EA-90-01

ENVIRONMENTAL ASSESSMENT BOARD

Ontario

ONTARIO HYDRO DEMAND/SUPPLY PLAN HEARINGS

VOLUME: 132

DATE: Monday, April 13, 1992

BEFORE:

HON. MR. JUSTICE E. SAUNDERS	Chairman
DR. G. CONNELL	Member
MS. G. PATTERSON	Member

FARR & ASSOCIATES REPORTING INC.

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EA-90-01

ENVIRONMENTAL ASSESSMENT BOARD
ONTARIO HYDRO DEMAND/SUPPLY PLAN HEARING

IN THE MATTER OF the Environmental Assessment Act, R.S.O. 1980, c. 140, as amended, and Regulations thereunder;

AND IN THE MATTER OF an undertaking by Ontario Hydro consisting of a program in respect of activities associated with meeting future electricity requirements in Ontario.

Held on the 5th Floor, 2200 Yonge Street, Toronto, Ontario, Monday, the 13th day of April, 1992, commencing at 10:00 a.m.

VOLUME 132

B E F O R E :

THE HON. MR. JUSTICE E. SAUNDERS	Chairman
DR. G. CONNELL	Member
MS. G. PATTERSON	Member

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I N D E X o f P R O C E E D I N G S

L I S T of E X H I B I T S

LIST of UNDERTAKINGS

TIME NOTATIONS

---Upon commencing at 10:03 a.m.

THE REGISTRAR: Please come to order.

This hearing is now in session. Be seated, please.

THE CHAIRMAN: Ms. McClenaghan.

MS. McCLENAGHAN: Thank you, Mr. Chairman.

I intend today to enter and deal with two exhibits if I may. The first exhibit is a package entitled: Materials Relating to Radioactive Emissions, Health, Environment and Regulation, and I understand that Exhibit No. 597 is available.

THE CHAIRMAN: 597.

---EXHIBIT NO. 597: Package entitled Materials Relating to Radioactive Emissions, Health, Environment and Regulation.

MS. McCLENAGHAN: And later on today I will be dealing with a second package of exhibits entitled: Materials on Inherent Hazard and I understand that Exhibit No. 598 is available.

---EXHIBIT NO. 598: Package entitled: Materials on Inherent Hazard.

THE CHAIRMAN: Thank you.

MS. McCLENAGHAN: Both of those exhibits, Mr. Chairman, have bold page references on the top right corner of each page of the exhibit and it will be

those numbers that I will be referring to as we go

THE CHAIRMAN: And as we go through, some of them we also -- I didn't realize this is becoming sort of a maze, but sometimes we give documents another exhibit number, even though they are internal to this one, and also if interrogatories are mentioned we also put them on an interrogatory list. It might help in cross-referencing later on.

MS. McCLENAGHAN: Yes. Thank you, Mr. Chairman.

THE CHAIRMAN: So sometimes there are little interruptions about that sort of thing and you will have to just bear with us on that.

MS. McCLENAGHAN: Yes, I understand that. And there are, in fact, some interrogatories included in these packages.

DAVID WHILLANS,
KURT JOHANSEN,
FRANK CALVIN KING,
WILLIAM JOHN PENN,
IAN NICHOL DALY; Resumed

CROSS-EXAMINATION BY MS. McCLENAGHAN:

Q. Mr. Johansen, I would like to mention your testimony from your direct evidence and in particular your slide 52 of Exhibit 519, which dealt with volume of radioactive waste.

A. Yes, I have it.

Q. And that was, as my reference is, at page 21338 of Volume 122, where I recall you testified that Ontario Hydro would have produced a total of 75,000 tonnes of radioactive spent fuel by the end of the 40-year lifetimes of the existing plants. Was that the evidence?

A. That's correct.

Q. And you said to put it into perspective, you said if you put it in a hockey rink it would fill it to a height of 21 metres, and that's what you said?

A. Yes, that assumes that the fuel would be stored in modules similar to those used in the storage bays.

Q. Now, my question is whether it's the weight and the volume of those wastes which you would characterize as their most important characteristics?

A. Probably the volume, although I think the key characteristic is the toxicity or the hazard. I think either weight or volume are relatively small and manageable that they are not in my view the predominant characteristics.

Q. So the characteristic that we are to be most concerned about as you say is their toxicity?

A. That's correct.

Q. Can you describe why it is that they are toxic or how they are dangerous, what the characteristics are that make them toxic?

A. Well, Dr. Whillans can probably assist me. But as I indicated in my direct evidence, the primary characteristic, I guess, of the used fuel when it comes out of the reactor is the fact that it is highly radioactive.

Q. Yes. And as a result of that they are known to be carcinogenic; is that right?

A. That's my understanding but that's Dr. Whillans' domain.

Q. Dr. Whillans?

DR. WHILLANS: A. Well, the assumption is simply that ionizing radiation is carcinogenic, yes.

Q. And at page 57 or slide 57 of Exhibit 519, that slide, as I understand it, quantified low and intermediate wastes as well only by volume or weight and not by radioactivity; is that right?

MR. JOHANSEN: A. That's right.

Q. And it showed that the total volume was dominated by low level wastes; is that right?

A. That's correct.

Q. Now if those wastes were quantified by their radioactivity instead of by their volume, what

would be the relative importance of those three categories? Do you have any percentages?

A. Offhand I don't, but I'm sure we could provide that information.

Q. Well, you would agree with this that if you quantified them by radioactivity, the type 3 wastes would be just about as dominant as the type 1 wastes. Is that a fair statement?

A. I'm not sure that we could necessarily equate them but certainly the difference would be less than is indicated by a volumetric comparison.

Q. I'm sorry, I didn't catch the last part of your answer.

A. If as you suggest a comparison were made on an activity basis as opposed to a volumetric basis, the difference would be less than is indicated in this slide on page 57.

Q. And when you say activity, of course you always mean radioactivity?

A. That's right.

Q. I would like to refer you to page 156 of Exhibit 597, which is an excerpt from Exhibit 256 in this hearing. It begins at page 151 and it's the Ontario Hydro Annual Environmental Performance Report,

1990.

THE CHAIRMAN: Can you give me that again, please, the exhibit number?

MS. McCLENAGHAN: The DSP Exhibit No. is 256.

THE CHAIRMAN: Thank you.

MS. McCLENAGHAN: And the excerpts here are found beginning at page 151.

Q. Figure 9.7B is a graphic representation of solid radioactive waste between 1986 and 1990. And it has a shaded area indicating intermediate level wastes, type 2 and 3, and a clear area indicating low level wastes, type 1 only; right?

MR. JOHANSEN: A. Figure 9.7B?

Q. Yes.

A. Yes.

Q. It would appear from this graph that the intermediate level wastes, type 2 and 3, are gradually getting bigger as a percentage of the volume of the total. It's difficult to tell without specific numbers, but that's what it looks like; is that right?

A. Well, certainly, the proportion for 1990 is greater than that for 1989, but it doesn't appear to be all that different from the value shown for 1988. So, I don't think there is enough there to

suggest that there is a gradual increase.

Q. On page 155 of the exhibit or 25 of the document itself, towards the top of the right-hand column you will see a sentence that begins "Intermediate level waste, type 2 and type 3...." Do you see that?

A. Right-hand column?

Q. At the top, about the first full sentence, second full sentence.

A. Yes.

Q. It says:

> Intermediate level waste, type 2 and type 3, makes up 2 per cent of the waste and contains 98 per cent of the activity.

And I take it you would agree with that?

A. Yes. I have no reason to doubt that figure.

Q. And again that's 2 per cent by volume, not 2 per cent by toxicity?

A. That's right.

Q. Is there any particular reason why you aren't presenting the information to us in terms of percentage of toxicity?

A. I think, in my direct evidence you are wondering--

Q. Yes.

A. --or in general?

Q. In your direct evidence, in your overview of the kinds of wastes that you are producing.

A. Well, in my direct evidence, my objective was to indicate the magnitude of the management challenge. The nature of the facilities used to manage these materials is intended to deal with the characteristic of the waste in terms of radioactivity.

[10:15 a.m.]

But it's the volume that we felt was relevant to the question, how large a management problem is it. That is why I chose to show you a volumetric comparison. But we do provide information on the radioactivity characteristics of the waste as well.

DR. WHILLANS: A. May I add a comment?

Q. Yes.

A. I don't think we should equate activity and toxicity necessarily, because availability for exposure comes into it as well.

I agree that activity is a closer measure of what you call toxicity, but I don't think it is necessarily equal.

Q. I take it that both of you would agree that the other characteristic of this waste which is critical in any consideration, whether it's management or availability for exposure or anything else, is how long it lasts; is that right.

MR. JOHANSEN: A. That's certainly one important characteristic.

I might just add in further response to your previous question about volumetric or radioactivity characteristics, that in the document which we provided in response to Interrogatory 9.9.41, entitled: Radioactive Materials Management at Ontario Hydro: An Overview, this is a document that we referred to frequently in responses to interrogatories.

Table 3-4 in that document presents the type 1, type 2, type 3 wastes in terms of both volume and total radioactivity, and there are other documents that present these materials in similar terms.

THE CHAIRMAN: Is the interrogatory already recorded?

THE REGISTRAR: Was that number?

THE CHAIRMAN: 9.9.41.

MR. B. CAMPBELL: I believe it's 520.19, Mr. Chairman.

THE CHAIRMAN: Thank you.

MS. McCLENAGHAN: Q. So in your earlier response to this question you indicated that one of the reasons or the reason that you considered volume most important was because you are assuming, I take it, that your management of the wastes will ensure that there are no problems from its toxic characteristics?

MR. JOHANSEN: A. That's generally true. And I might add, I don't think I said it's the most important. It is an important characteristic.

Q. Its toxicity or its volume?

A. Its volume.

Q. I would like to refer to you page 2 of Exhibit 597, which is an excerpt from the Royal Commission on Electric Power Planning, and page 2 is a graph titled: Ingestion, Toxicology of Spent CANDU Reactor Fuel, Once-Through Natural Uranium Cycle.

First of all, would you have any reason to disagree with the data contained on that graph as to the total ingestion toxicity of the fuel?

A. Well, I can comment, Dr. Whillans might wish to add a comment.

What I would say is that the Porter Report, the interim report issued by the Royal Commission qualified this curve, describing it as a crude measure of the potential danger of radioactivity

in the used fuel, and I would certainly agree with that.

One of the difficulties I have with this curve is the fact that it presumes that the radioactive content of the used fuel is desolved somehow in water, which doesn't recognize the relative insoluability of the fuel. It's ceramic in form, it's encased in a durable metal sheath, and it's difficult to envisage how used fuel in that ceramic form could become freely available in a water body such that this kind of way of presenting toxicity would be relevant.

But having said that, the technical parameters or values presented in this curve, assuming that the used fuel were somehow totally ground up and dispersed in water, are probably in the ballpark. But I really have difficulty with this form of presenting toxicity.

Q. Well, if we continue --

DR. WHILLANS: Can I also comment?

Q. Yes.

A. I just want to point out that the horizontal axis for this graph goes out to 10 million years, and I am sure you are well aware that there are major uncertainties in projecting over that period, and these have to be taken into account in any decisions

you base on data like this.

Q. All right. Is it fair to say, first of all, that what this graph is showing is, in terms of years, the amount of time it would take for radioactive decay to occur in the particular wastes that it's demonstrating?

A. I think Mr. Johansen is more familiar with this particular graph than I am, but I assume the way only you meet such a curve would be to assume only radioactive decay, because we don't know what kinds of dissolution might happen in a million years and so forth.

Q. If we look at 100 years, which is 10 squared, right, I take it you would agree there is less uncertainty over that time span.

MR. JOHANSEN: A. Yes.

Q. And if we look on the vertical axis, it would appear that -- well, first of all, ingestion toxicology is footnoted to say it's the volume of water required to dilute the wastes to public drinking water standards.

A. Yes.

Q. So then the graph on the vertical axis is indicating how much water is that, and that's per 1,000 megawatt/years. The amount of waste you are

producing in 1,000 megawatt/years of operation; is that right?

DR. WHILLANS: A. Excuse me, where does it say that?

MR. JOHANSEN: A. It's not actually indicated on here.

Q. No, I understand that is in the report but we don't have that excerpt for you, with my apologies.

If we make that assumption for a moment, because I think we could check that and confirm it, that this is graphing the toxicity of 1,000 megawatt/years of fuel from operation, then the amount of water that is required to dilute that fuel to drinking water standards appears to be, according to the graph, more than 100 billion cubic metres. Is that what it looks like to you?

A. That's what the graph shows, yes. But again I have to emphasize that this presumes that you, for some reason, would grind that ceramic fuel up into powder and released it to the water body, which is not a very realistic scenario at all.

DR. CONNELL: Excuse me a moment. The figure you were searching for was the 10 to the 13th? You rendered that as 100 --

MS. McCLENAGHAN: I think 10 to the 12th.

DR. CONNELL: Ten to the 12th, that would be 1,000 billion.

DR. WHILLANS: 1,000 billion.

MR. JOHANSEN: It's a very large number.

MS. McCLENAGHAN: Q. And you would agree with me that this is an area where it's very difficult to comprehend the issue of how much toxicity there is; is that fair?

MR. JOHANSEN: A. It's difficult to comprehend, I would say that's fair, yes.

Q. So that's why there might be use made of crude graphs like this that demonstrate the amount in something we can understand like how much it would take to dilute it to drinking water standards.

[10:27 a.m.]

That would be a reason for using this term "ingestion toxicity"; is that fair?

A. Well, I don't think that this sort of chart plays much of a role in radiation protection or the regulation of the management of used fuel. So, it's not something that we commonly use and it's not commonly used by the regulators, so I really can't agree that it serves much purpose.

Q. Would you agree that, as I understand

it, the eight Pickering reactors would generate in three perfect months of operation about this much radioactivity: 1,000 megawatt/years?

A. That would be approximately true.

Q. So that's what we are talking about, three months at one of your stations -- or two of your stations, at one of your locations?

A. 1,000 megawatts per year is what we are talking about or is what you suggested.

Q. And so what we are talking about is that that much generation results in this much waste whether or not the waste dissolves in water or is going to dissolve in water, that is how much waste has been produced by that operation; is that fair?

A. Yes, one gigawatt/annum to put it simpler terms produces something like a 140, or thereabouts, megagrams or metric tonnes of used fuel. That's a figure that we use routinely in our analysis and we have used that in our Exhibit 507, for example, so that's what we are talking about.

Q. I take it that you would agree with me that you couldn't think of any other way to generate electricity that would produce this amount of toxic waste?

A. Well, I don't think that's a

different question, is it? I'm not quite sure what you are asking there. If we couldn't think of any other way of producing the electricity, that is what would result from one gigawatt per annum of nuclear power generation, yes.

DR. WHILLANS: A. I think we should point out that in the direct evidence it was described that all of the waste fuel of the active waste from Pickering since it started operation in '71 is still stored in a relatively small pool, and I think that contrasts with the kinds of volumes you are talking about here.

Q. Just let me restate the question I am asking though. We have looked at how much waste a relatively small amount of operation has produced, i.e., Pickering for three months has produced the volumes of waste we were just describing. And my question is: Are you aware of any other form of electric generation that produces this kind, this amount of toxic waste?

THE CHAIRMAN: You mean radioactive toxic waste?

MS. McCLENAGHAN: Any toxic waste, radioactive or otherwise.

Q. Can you think of any other electric

generation that produces toxic waste on anything the order of this amount of toxic waste?

THE CHAIRMAN: I don't know how you can properly answer that. Your are talking about apples and oranges, different kinds of toxicity --

DR. CONNELL: SO(2) would be toxic for example.

MS. McCLENAGHAN: Q. Let's talk about it in terms of these kinds of volumes. This scale says that it would take, if I stand corrected, 1,000 billion cubic metres of water to dilute that much toxicity to public drinking water standards. Is there any other form of electric generation that produces that much toxic waste?

MR. JOHANSEN: A. The first response to your question is that I have not personally done an evaluation of the total hazard associated with waste products produced by other means of generating that same amount of electricity. And I am not aware that anyone else in our company has done it in those terms either.

But certainly virtually any method of producing electricity does produce by-products which are to some extent hazardous, and it would be quite an undertaking I believe to go through and to do a hazard

evaluation on a unit weight or volume basis. There is no hazard-free way of producing electricity I guess is one way of putting it. But I don't have a comparison of the sort that you are asking for.

Q. So, am I to understand that although we are involved right now in an Environmental Assessment of the Demand/Supply Plan, that's why we are here, you are saying there has been no comparison of that sort done by Ontario Hydro.

MR. B. CAMPBELL: With respect, Mr. Chairman, that's exactly not what the witness stated. What he is talking about here is a concept of dissolving all wastes from any source into water and then diluting it to drinking water standards for those particular things, a comparison which these witness have said is not useful in any event and have not done. There is all kinds of information provided comparing the relative effects, emission streams, et cetera, provided in the course of this hearing.

MS. McCLENAGHAN: Q. Maybe I did misunderstand what you said, Mr. Johansen. You are saying that there hasn't been a comparison done. Can you advise me of what it is that hasn't been done?

THE CHAIRMAN: Well, I take it that they haven't decided how much water would take to dilute

SO(2) to drinking standards. They haven't made that kind of analysis. I think that's what --

MR. JOHANSEN: That's exactly what I meant.

Panel 8 presented considerable evidence on the hazards of by-products generated in that way and, I understand, also presented a comparative analysis with alternative means of producing energy, but I am not aware that any of that information was presented in the form of so many volumes of water required to dilute it to drinking water standards.

MS. McCLENAGHAN: Q. Would you be able to advise me as to what is the total toxic inventory of a CANDU reactor?

DR. WHILLANS: A. Perhaps you could explain what you mean by toxic inventory? You want to know the total amount of activity resulting from so many years of operation?

Q. Yes, yes, let's assume 1,000 megawatt/years.

A. I am certain those numbers are available. I don't have them in my head.

Q. So, are you indicating that you could obtain that information for us?

A. Information about the amount of

activity resulting from the operation of 1,000 megawatt/years, yes.

Q. Thank you. Whatever amount it is, you would agree with me that there are potentially three places that that radioactivity ends up, if I can put it that way.

THE CHAIRMAN: Just a moment, perhaps we should record that as an undertaking. 520 point?

THE REGISTRAR: 8. Sorry, 532.8.

THE CHAIRMAN: That's my fault.

THE REGISTRAR: Thank you.

---UNDERTAKING NO. 532.8. Ontario Hydro undertakes to advise as to what is the total toxic inventory of a CANDU reactor resulting from 1,000 megawatt/years. And also to advise what percent or radioactivity might be emitted during routine operations as a fraction of the total inventory.

MS. McCLENAGHAN: Q. So my question is: That you would agree with me whatever the number is, you have got radioactive materials in the reactor and there are three, as I understand it, three places it can end up, if I can use that phrase. One is that some of it would be emitted during routine operations; is that fair?

MR. JOHANSEN: A. Yes, that's correct.

Q. If there was, Lord forbid, an

accident, then some of it could be emitted in an accidental way?

A. That would be correct. Mr. King might want to add something to that.

Q. And the third way is that whatever is left after you are finished with the fuel, then becomes radioactive waste and needs to be stored somewhere until it is harmless; is that fair?

A. That's correct.

DR. WHILLANS: A. I think there is a fourth important mechanism for getting rid of activity and that is radioactive decay. Much of the activity that would be generated decays in such a short time that it can't leave the plant.

Q. Now in terms of the routine emissions of the radioactivity that is contained in the reactor, I understand that that is a small percent of what is in the reactor; is that fair?

MR. JOHANSEN: A. Yes, that's right.

Q. And would you have any ratio as to what per cent might be emitted in a routine way or during routine operations?

A. As a fraction of the total inventory?

Q. Yes.

A. Not offhand. We would need to have

the answer to the undertaking that we just took on to answer that. But I guess it would be a very, very small fraction obviously.

Q. Would it be maybe some millionths or some billionths of the total, do you think?

A. That would be a speculation, purely. I prefer to not speculate on that.

Q. All right. We can revisit that question when we have the answer to the earlier undertaking.

THE CHAIRMAN: Perhaps it can be incorporated into the earlier undertaking as part of it, so we don't need to give it new number.

MS. McCLENAGHAN: Thank you, Mr. Chairman.

DR. WHILLANS: So we could add to the total activity generated by one gigawatt/year of operation the amount or fraction of activity emitted during one year. We are comparing slightly different bases here because a gigawatt/year doesn't necessarily happen over a whole year. We can give you both figures and then you can see what you....

MS. McCLENAGHAN: Q. Now in terms of the routine emissions of the radioactivity from the reactor, I take it that there are two ways that that

happens. One is unintentional and the other is intentional. Is that fair?

DR. WHILLANS: A. I think we are having a little trouble deciding who should be answering these because I spoke about the emissions in terms of health effects and Mr. Johansen is the environmental specialist. But personally I don't think I would agree with that division particularly.

Q. And how would you disagree?

A. Well, to distinguish between deliberate and accidental I think is too simple. Certainly we have controlled releases and I guess you would want to call those deliberate. And we have some that are unplanned and I guess you want to call those accidental.

But I think that controlled is a better term.

[10:40 a.m.]

Q. All right. Well, let's use those terms then.

You have some emissions which you control and plan to emit, and others which you don't plan to emit, but you emit anyway; is that right?

A. I am not sure we have changed the definition, but okay, let's talk on that basis.

Q. Now, as I understand it, Ontario Hydro - and you can correct me if your understanding is different - but Ontario Hydro doesn't measure how much of that radioactivity which escapes from its reactors emits by way of controlled or planned emissions versus how much escapes by way of unplanned emissions; is that right?

A. I am sure Mr. Johansen has a comment to add. But the pathways by which either of those can reach the environment through the air, up the stack or to the water, are monitored. And so we monitor both the controlled and the, if you want to call them, accidental.

I think what we have said was we can't necessarily give you a number of how much was controlled and how many wasn't, because the definition becomes a bit fuzzy.

Do you want to add anything?

MR. JOHANSEN: A. Only that we do measure them both. I think there was a suggestion in your question that perhaps we didn't, as least that's the way I interpreted it. And secondly, I believe that this was the subject of an interrogatory, 9.2.126--

Q. Yes. That's at page 144.

A. --which we have responded to.

Q. Page 144 of the exhibit package. And as I read that response it says --

THE CHAIRMAN: Just one moment. Have we got that have one recorded, 9.2.126?

THE REGISTRAR: That will be .91, Mr. Chairman.

---EXHIBIT NO. 520.91: Interrogatory No. 9.2.126.

DR. WHILLANS: I think this response says what I just stated, that we monitor all the pathways, all the major pathways which could be available for either a planned or unplanned release. And the reason that we don't have the records and the detail required to give a response to your question is that we don't make the distinction between a routine release and an unplanned release in every case.

The response also points out that the reason we don't keep records in this detail is because the total from the planned and unplanned is almost always way, way below the regulatory limits.

MS. McCLENAGHAN: Q. So you wouldn't be able to say, though, because you don't distinguish in your monitoring, you are just measuring the pathways, not what portion of that pathway has come from a planned emission, you wouldn't be able to assess how much reduction you could put into place relatively easy

or in some manner, vis-a-vis your planned emissions; is that fair, because you don't know how much of it is planned?

DR. WHILLANS: A. But, again, I think it's not obvious that a reduction methodology, for example, wouldn't apply equally. If you put a control on how much goes out by airborne, for example, it could apply to what you want to call controlled and what you want to call accidental.

I think we should be clear that what you are calling accidental is not the result of a station accident; we are talking about things that are approaching routine.

MR. JOHANSEN: A. They are anticipated; they are not scheduled.

Q. So that what you are saying is that in some cases if you took an abatement measure, you might reduce both, planned and unplanned, because the abatement measure might apply at the discharge point, whatever that was; is that fair.

DR. WHILLANS: A. I agree with that.

Q. But isn't it the case that in other situations what you might be able to reduce are your unplanned or unintentional if the emissions are occurring by way of leaks or some kind of faulty

equipment in some way?

A. There are many ways in which emissions could be reduced.

MR. JOHANSEN: A. You can reduce them, for example, by eliminating the source, and you can reduce them by controlling them at the point of discharge, or by improving your monitoring or detection so that your reaction time is less. There are a number of ways that can be and in fact are being used.

Q. Now, I would like to refer you to page 150 of the exhibit, which is an interrogatory, No. 9.2.127.

THE REGISTRAR: .92.

---EXHIBIT NO. 520.92: Interrogatory No. 9.2.127.

MS. McCLENAGHAN: Thank you, Mr. Registrar.

Q. As I understand that interrogatory, Ontario Hydro intentionally pumps out radioactive liquid waste from its plants, one tank of low activity radioactive liquid waste per 12 hour shift is what this interrogatory states; is that right?

MR. JOHANSEN: A. That's generally true.

Q. And if the wastes in the tank meet your preset radioactivity specifications then you release them to the environment as they are; is that

right?

A. Yes, only after they have been monitored and determined to be below the required operating targets are they released.

Q. Right. And if they are not, then they are treated first and then they are released; is that right?

A. That's correct.

Q. I would like to turn to one of the specific components of your emissions and that's the tritium emissions. And the first two questions are questions which we had given you notice of question concerning.

The first is: How much tritium will the Darlington nuclear generating station, exclusive of the tritium removal facility, have at its maximum at any time of its life?

DR. WHILLANS: A. Could you help me with a reference for that?

Q. In terms of the notice of question?

A. This was on a separate sheet. It's not included?

Q. Right. We had sent a notice of question dated March 19th.

A. I have it. This is the letter from

yourself to Ms. Harvie?

Q. Yes, that's right.

MR. KING: A. Excuse me, Ms. McClenaghan, the question you wanted to talk about? I think we found your notice of question and...

Q. Yes. The question was: How much tritium will Darlington nuclear generating station, exclusive of the tritium removal facility, have at its maximum at any time of its life, and then what will be the size of the tritium inventory at Darlington exclusive at the tritium facility at any given time?

DR. WHILLANS: A. When you exclusive of the TRF, do you mean exclusion of any stored tritium as a result of the operation of the TRF as well? You are asking just about a four-unit station?

Q. Yes.

MR. KING: A. We have a curve of tritium buildup over time for Darlington expressed in curies per kilogram of heat transport system water, and this, I believe, assumes that the tritium removal station has not been used to clean up that water.

So, of course, with a half life of 12.3 years, then you are building up over time and you are getting towards an equilibrium. And at 40 years the value that I have here is 30 curies a kilogram. And

actually, the amount of water is around 260 megagrams per unit.

Now, if anything, of course, if you do use --

THE CHAIRMAN: The 30 value was for four units?

MR. KING: No, that applies to any unit.

And if you are interested in any other time during the 40-year life, I have that value in front of me right here as well.

But then, in future there may be action to apply the tritium removal facility to the water in that system and hence the value could in fact be lower than that. But that's the value assuming that you do not use the tritium removal facility on the system.

MS. McCLENAGHAN: Q. So what would the total be at any one time?

MR. KING: A. Well, it should be, following all those assumptions, that you don't use the tritium removal facility, it should be 260 -- well, the value is right in front of me. It would be 260 times 4 times 30, which I have as 31,200 curies. That doesn't seem to be quite right.

If you leave that number on the table for now, I will, at the break, go through it again.

DR. WHILLANS: A. I don't know if this helpful, but I think there is a danger of confusing ourselves and perhaps the Board because we talk about becquerals, we talk about curies, and we often about grams of pure tritium.

And just as a general number the production rate of tritium in a 14 gigawatt system, our system, is about a kilogram per year, that's in all reactors, and at equilibrium it will go to approximately, I think, 16 kilograms. And, of course, with the operation of the TRF, those levels will not be reached in the future because we are removing tritium from the individual station systems and storing it at the Darlington site, but as part of the TRF, which you didn't want included in your answer.

DR. CONNELL: Could I just interject here, a cross-reference to transcript Volume 122, page 21421, I was discussing this matter with Mr. Johansen and Mr. King. I asked at line 14:

"Is this reaction predominantly in coolant or in the moderator or both?"

And Mr. Penn says: "It occurs at both."

When I said, "Which is predominant?", Mr. King said:

"There is more moderator in the core

at any one time, so it would be
primarily in the moderator."

I gather we have been discussing just the heat transport system in the last minute or two; is that correct?

[10:57 p.m.]

DR. WHILLANS: I think we have been discussing both.

MR. KING: No, the question was related to the heat transport system. Or I'm sorry, that's the one I interpreted.

DR. WHILLANS: Certainly the numbers I was giving were for everything.

MS. McCLENAGHAN: Q. The original question was how much would it have at its maximum at any time of its life.

MR. KING: A. I interpreted the question to be the heat transport system. I can give you other numbers for the moderator system if you would like.

Q. Yes.

A. And the number for the heat transport system is 31.2 million curies for four units. The heat transport system at Darlington at 40 years, at the end of 40 years, assuming that the tritium removal facility has not been used to remove tritium from that water.

DR. WHILLANS: A. I think the other number that is useful here is that the specific activity of tritium is about 10 to the fourth curies per gram.

MR. DALY: A. I should add that in terms of removing the tritium from an operations point of view, we would aim to get the tritium level down to about 1 to 2 curies per kilogram in the heat transport system, probably a little more in the moderator system; it tends to be more difficult. So I think you should bear that figure in mind as a contrast to the 30 curies per kilogram at the end of 40 years without the TRF that Mr. King mentioned.

MR. KING: A. I can complete that answer for the moderator system now.

Q. Yes.

A. I will give it to you without the TRF and I will give it to you with the TRF because of course Mr. Daly is correct.

So for the moderator system at Darlington again with the following assumptions, no TRF removal, four units at the end of 40-year life, the concentration of tritium, if you will, would be somewhat just below 80 curies a kilogram. That would lead to a total inventory of 99.2 million curies of

tritium.

But as Mr. Daly has indicated, the intention is to use the tritium removal facility. And therefore on the heat transport systems rather than having a concentration -- or a moderator system, I should say. Rather than having a concentration of close to 80, I believe it is closer to 2 or 3 - that's the information I have in front of me - curies per kilogram, so that 99.2 million figure, you would have to reduce that by a factor of -- well, the ratio of 80 to 2 or 3, so a factor of 40 to 25.

So, we are down there at a much smaller number. The intention in the heat transport system it would be at the lower value, about 1 curie per kilogram is the information I have in front of me, so it would be a factor of 40 less than the 33 million figure I gave you.

Q. If I refer you to your interrogatory No. 2.2.8, which is at the exhibit pages 125 to 131 or so --

THE REGISTRAR: 2.2.8 is .93.

---EXHIBIT NO. 520.93: Interrogatory No. 2.2.8.

MS. McCLENAGHAN: Q. Now as I understand it from that interrogatory, which was revised a couple of times, in the five years between 1986 and 1990

Ontario Hydro at Bruce and Pickering stations emitted a total of over 850,000 curies of tritium in the form of tritium oxide into the environment, both airborne and waterborne; is that right?

THE CHAIRMAN: Are you taking that from an interrogatory?

MS. McCLENAGHAN: Yes. The interrogatory in the exhibit --

THE REGISTRAR: I can't hear you,I'm sorry.

MS. McCLENAGHAN: In Exhibit 597 the excerpts pertaining to this interrogatory begin at page 125.

THE CHAIRMAN: Where do you get the 850,000? I'm not quarreling with you; I just want to find it.

MS. McCLENAGHAN: It is an addition of the numbers for Bruce and Pickering for airborne and waterborne emissions with the revised numbers, so it isn't stated at 850,000 in this interrogatory. But I am asking for confirmation that if you look at those two stations and look at airborne and waterborne that you get a total of emissions of 850,000 curies.

DR. WHILLANS: Are you saying that you have added figures for Bruce and Pickering from the

tables on page 128?

MS. McCLENAGHAN: Q. Yes. And 127.

DR. WHILLANS: A. And 127. And the number that you came to was?

Q. 850,000 curies of tritium in the form of tritium oxide.

A. And for which year were you doing the calculation?

Q. This was between 1986 and 1990.

A. So that's the total for all years?

Q. For the five years at those two stations.

A. I guess subject to check I would think it looks not unreasonable because the individual entries are of the order of 10 to the 4, and you are quoting 8-1/2 times 10 to the 5, so it's something in the ballpark, yes.

Q. And if you translated the curies into terabecquerels or becquerels, as I understand it, you would arrive at 31 quadrillion becquerels. Does that sound right?

A. [Laughter] Can you give us a second here. This is for your number of 850,000 curies?

Q. Yes.

A. And your number was again, sorry?

Q. 31 quadrillion becquerels.

A. 31 quadrillion.

Q. 31 times 10 to the 15th.

A. Okay. Well, I have a number that is very similar to that, okay. Petabecquerels is 10 to the 15th.

Q. Dr. Whillans, I recall that you testified earlier that you were familiar with the concept of an LD50 in dealing with toxins, i.e., that that means the dose of a toxic that could be expected to kill 50 per cent of the recipients within some specified time period?

A. Generally, yes.

Q. And as I recall, you testified that an LD50 dose to a human adult was between 2-1/2 and 5 sieverts?

A. Yes.

Q. So, if we used say 4 sieverts to do some calculations, would that seem fair?

A. Yes. I did say that this is an uncertain number because there haven't been that many exposures well monitored, and it also I think depends very much on the state of support of medical care. But that's a good number within a factor of 2.

Q. All right. And would you also agree

that the dose to a human adult population statistically associated with a single fatal cancer is around 12 sieverts or 12 person sieverts?

A. Can you give me second on that one. Well, the numbers I'm working with are that the --

THE CHAIRMAN: Excuse me, Dr. Whillans. Could you just give me the question again, please.

MS. McCLENAGHAN: The question was whether he would agree that a dose to a human adult population that is statistically associated with a single fatal cancer is around 12 person sieverts.

DR. WHILLANS: As I started to say, the number I am working with is the risk number from ICRP, for example, of 5 times 10 to the minus 2 per sievert for the induction of a fatal cancer. All right? So I would make that perhaps 20 sieverts, 20 person sieverts.

MS. McCLENAGHAN: Q. And would you agree when you are arriving at that different number that your difference is due to a theoretical dose and dose rate effectiveness figure -- or factor, sorry?

DR. WHILLANS: A. The number of 5 times 10 to the minus 2 does include for solid cancers a dose rate effectiveness factor of 2, yes.

Q. And would you agree that there is --

A. I'm not sure I would agree it is theoretical. It's based on laboratory measurements rather than human epidemiology.

Q. Right. So you would agree that there is no direct evidence of that factor, the dose and dose rate effectiveness factor for humans?

A. There are measurements of human populations, as I mentioned in my direct evidence, that are used in addition to the major evidence which is from the Hiroshima/Nagasaki data. These measurements are on people who have received diagnostic or therapeutic radiation or occupational exposures.

And that evidence is not as strong, for sure, as the Hiroshima/Nagasaki data, but it tends to suggest that exposures are less effective in the induction of cancer when they are received at low dose and dose rate. Now I will admit that that evidence is not at all strong, and the major reason that the ICRP, for example, includes this dose rate effectiveness factor of 2 is because of the laboratory studies that have been done on animals, and there it's much clearer.

Q. So it's clearer on mice?

A. Mainly in rodents, yes.

I should also say that there is a wide range. The animal studies suggest a range of a factor

of about 2 to 10, and so 2 is the smallest of that range.

Q. Would you be able to tell me how much tritium an adult would have to ingest or in inhale to receive that LD50 dose of radiation?

A. Yes, I would. Do you want me to do that?

Q. Yes. And I can refer you to your Interrogatory response 9.22.6.

A. Could you repeat that?

Q. 9.22.6 or....

THE REGISTRAR: 9.2.6 is .94.

MR. B. CAMPBELL: I believe it may be .14 already.

THE REGISTRAR: This is the point. I have 90-odd numbers here to check and unless the lady gives me the page number that she is going to refer, I can't check it off.

THE CHAIRMAN: 14?

MR. B. CAMPBELL: Yes.

MS. McCLENAGHAN: To assist the Registrar and the witnesses, the excerpt is contained at page 6 and 7 and 8 of the exhibit.

DR. WHILLANS: I would like to point out that this report is 1986 and tritium dosimetry has

changed since then.

Sorry, what page did you refer me to?

MS. McCLENAGHAN: Q. It is page 6, 7, and 8 of the exhibit.

DR. WHILLANS: A. Of your exhibit?

Q. Of our exhibit.

A. We should get the same answer by using these tables, but the number that I use in dosimetry, I know that the so-called annual limit on intake for an occupational exposure, which means that it will result in a 50 millisievert exposure is - I'm sorry, I have to use these units - 68 millicuries, so a 5 sievert exposure would result from an intake of 6.8 curies. So if you wanted a 4 sievert exposure, it would be four-fifths of that value. Do you want that in becquerel?

Q. Yes, please.

A. So if we call it 5 curies, I think I would make that between 1.5 and 2 times 10 to the 8th becquerel.

---Off the record discussion.

DR. WHILLANS: Mr. Johansen says 1.9 times 10 to the 8th becquerel.

MS. McCLENAGHAN: Q. So you are saying that's the -- sorry.

THE CHAIRMAN: He has not quite finished, I don't think.

MS. McCLENAGHAN: Q. Sorry, go ahead.

DR. WHILLANS: A. You preferred to use Table C-1, I guess, so perhaps we should cross-check it. I have forgotten. Were you talking about an adult or general population?

Q. An adult.

A. Well, I guess doing it this way it would be 5 divided by 2.0 times 10 to the minus 11 and that comes to, I guess 2-1/2 times 10 to the 11 becquerels -- sorry, it was four, wasn't it? So it's still the same number: 1.9 times 10 to the 11th becquerel.

DR. CONNELL: We had 10 to the 8?

DR. WHILLANS: Sorry?

DR. CONNELL: I thought you said 10 to the 8, doing it the other way around.

MS. McCLENAGHAN: Q. But I think you mean 1.9 times 10 to the 11th?

DR. WHILLANS: A. I was wrong before, yes. It was my conversion factor. So let's call it 2 times 10 to the 11 becquerel and that corresponds to 4 sieverts of tritium dose.

Q. As I understand it, if we were to

look at infant ingestion values, the figure would be about 3 times higher?

Is that your understanding?

A. That's right.

Q. Or three times less tritium would result in the same LD would result in an LD50 --

A. The dose factor for an infant as shown in page 7 of your exhibit is almost three times that for an adult.

Q. As I understand it, this much tritium is about half a milligram of tritium.

Is that about right?

[11:15 a.m.]

A. Unfortunately, I carry the conversion factor from the curies to kilograms in my head. Now, we have to go back to get becquerels, I guess.

Wait a minute, I was claiming this was about 4 curies.

Now what was the number you gave again?

Q. About half a milligram of tritium.

A. I have to add that all of these quick calculations I think should be subject to check.

Q. That's fair.

A. But I think that is a reasonable number, yes.

Q. So, in other words, that tiny amount of tritium, half a milligram or so, is an LD50 adult dose?

A. This is half a milligram of pure tritium. Not even the tritium, the very high levels of the tritium in, for example, the moderator, whereas we said it was in the order of 20 curies per kilogram, we are talking about 10 to the 4th curies per gram. So you are talking about a quantity of tritium, and I agree that's probably ingestion LD50.

DR. CONNELL: This is T(2), not T(2)O?

DR. WHILLANS: Yes. We are being a little careless because there is a difference in the molecular weights.

It's fully substituted tritiated water, so it is 2 tritiums and an oxygen, or you get a slightly different number if you were talking T(2).

DR. CONNELL: It would be eightfold.

DR. WHILLANS: It's eightfold, yes.

But the difference I was trying to point out was that you are talking about half a milligram of pure tritium or some slightly different number, eightfold different number of fully tritiated water. But even in the moderator, which we were talking about at the order of 30 curies per kilogram, it is not at

all fully tritiated. So this is quite a hypothetical kind of source.

MS. McCLENAGHAN: Q. Yes. And you would agree that this calculation that you just did does take full account of the fact that tritium's beta particle has very little energy, or, in other words, is soft radiation; is that right?

DR. WHILLANS: A. The dosimetry factors take into account the energy of the emission, yes.

And since you point it out, a beta particle with a maximum energy of only about 18 KEV, as Dr. Connell was pointing out earlier in the hearing, would not pass through a glass of water, for example, a glass surrounding the water. It wouldn't pass through the skin.

Now, we do take into account toxicity through skin uptake because the tritiated water itself will pass through the skin, but any activity that remains outside the body is not toxic to the body.

DR. CONNELL: Just to follow up on that, if we go back to your testimony, Dr. Whillans, you said that pure tritium is 10 to the 4th curies per kilogram. Did that refer to tritiated water?

DR. WHILLANS: Curies per gram, sorry.

DR. CONNELL: Oh, my goodness. And

that's tritiated water, is it?

DR. WHILLANS: We are throwing around factors of 10 to the 3 and 10 to the 15 pretty casually. But it's 10 to the 4th curies per gram for a tritium atom.

DR. CONNELL: Right. And if the steady state in the heat transport system is 30 curies per kilogram, I assume that's also for --

DR. WHILLANS: That's per kilogram of moderator water.

DR. CONNELL: I think it follows, then, if we take this lethal dose of .5 milligrams and we convert that to steady state water, there is going to be a factor of 1.7 times 10 to the 6th in there, I think, in other words --

DR. WHILLANS: That sounds reasonable. I think the number I carry is that for moderator water, high activity water, something between a 10th and 1 litre would give you an LD50. So since we were talking about the order of a milligram, which is about a millilitre, I think that's about right, but I think we should probably check if it is important.

DR. CONNELL: So if you were offered half a milligram of it, you would probably swallow it without a second thought, would you?

DR. WHILLANS: Half a milligram of moderator water rather than pure tritium?

DR. CONNELL: Yes.

DR. WHILLANS: I have might have a second thought, but I would probably decide to swallow it if there were a benefit. [Laughter]

MS. McCLENAGHAN: Q. Well, Dr. Whillans, just to extend the hypothetical on a continued basis, and this is of course a hypothetical. The amount we looked at a few minutes ago, the 850,000 curies of tritium that had been emitted from Pickering and Bruce over those five years, if that amount were all consumed by human adults, then that would lead to an effective population dose equivalent of by our calculations about 155,000 LD50 doses.

DR. WHILLANS: A. Well, do you want us to check that number? I certainly can't confirm it without doing a calculation.

Q. All right. Does it sound like it's wrong to you or out of line, or do you want to say subject to check?

A. If you want to use that number in some subsequent questions, then I will accept it subject to check.

So the number again was? 1.5 times 10 to

the how many?

Q. 155,000 LD50 doses.

A. 10 to the 5 LD50s.

Q. And if we were using the 12 person sievert rate for fatal cancer, although I understand you mentioned 20, if we are using the 12 person sievert rate, those number of LD50 doses, if they were all consumed by human adults could be expected to lead to about 51,700 excess fatal cancers; would that be right?

A. Well, we really are going too far here I think. Maybe we should look back at the direct evidence, because we do calculate the total person sievert dose as a result of our emissions, and we calculate it for all the relevant populations, and the total in one year from all of our operations I think I gave as 1.75, and most of that was not tritium.

So we are talking about something in the order of a person sievert per year maximum, five person sieverts, and as I said again in the direct evidence, the number of fatal cancers that we believe may be induced as a result of all our operations, that includes the non-tritium emissions, was .1 per year, approximately.

So, you had a number of some numbers of thousands.

Q. Yes.

A. There is certainly something wrong with this calculation.

Q. Because it's a hypothetical. It's assuming that all of those emissions over the five years were consumed by human adults.

So my question is merely, if you made that assumption, which I recognize is extremely hypothetical, how many excess fatal cancers does that number produce on the dosimetry calculations we just went through?

A. Just to step back. The number you want me to confirm is that a certain number of emissions, a certain number of curies emitted over five years leads to a certain number of cancers; is that right?

Q. Yes.

A. And the number is 8.5 times 10 to the 5th curies--

Q. Right.

A. --of tritiated water. And the number of cancers you say is how many?

Q. 51,700.

A. 51,700. Do you want me to check that now or over the break?

Q. We can check that over the break. That's using 12 person sieverts for the excess cancer or the fatal cancer.

DR. CONNELL: I think we should have something to compare it to, perhaps ingestion of the equivalent in flyash or photovoltaic collectors.

DR. WHILLANS: Exactly. Perhaps Panel 10. [Laughter].

THE CHAIRMAN: Perhaps we could take the break now and we will continue in another fifteen minutes.

MR. B. CAMPBELL: Mr. Chairman, I'm sorry. Dr. Whillans and the others will no doubt get involved doing some calculations. Could we get 20 minutes so that they actually do get time having a little break and don't spend all their time doing calculations in what is supposed to be a break?

THE CHAIRMAN: All right, 20 minutes.

MR. B. CAMPBELL: Thank you.

THE REGISTRAR: This hearing will take a 20-minute recess.

---Recess at 11:30 a.m.

---On resuming at 11:50 a.m.

THE REGISTRAR: Please come to order. This hearing is now resumed. Please be seated.

DR. WHILLANS: I think I had agreed to check some numbers.

MS. McCLENAGHAN: Yes. Thank you, Dr. Whillans.

DR. WHILLANS: Could I add a couple of things first before I do the correction?

Dr. Connell had been helping with the conversion from tritium to tritiated water. I just wanted to point out that because we are talking about tritium, not hydrogen, the molecular weight is 6 and 22, so it's about a factor of 3, not 8.

DR. CONNELL: Thank you.

DR. WHILLANS: I also did check your .5 milligrams and I agree it's of that order. That's for pure tritium.

The corresponding number for the highest activity water is the order of a quarter of a litre. The difference is because of what Dr. Connell was pointing out.

Getting back to your number of fatal cancers. On the assumption that the emissions in those tables add up to 850,000 curies, which we haven't checked yet, and using the conversion factor on page 7 that we referred to earlier, gives a total collective dose of 6.3 times 10 to 5 person sieverts. I would

like to compare that with the -- this was over five years, but about 1 person sievert per year in our environmental summary. So this is where the difference is, as you point out.

If you take that 6.3 times 10 to the 5 person sieverts and on your assumption of on fatal cancer per 12 person sieverts, the number is about 52,000. So I do confirm your number. And as I say, the difference is because of the very much larger population exposure if you assume that everyone, every bit of that tritium emission is taken up by someone.

So basically I agree with your calculation on the assumptions that you made, but I think I should said again that they are pretty hypothetical.

MS. McCLENAGHAN: Q. And as you are just stating, the differences between the hypothetical and what you report as the reality come from basically two places, and you can tell me if I am right about this, firstly, that you are predicting, Ontario Hydro is predicting that most of the tritium that goes into the water or into the air will actually not be consumed by humans, that's your prediction.

DR. WHILLANS: A. I don't think we can call it a prediction because we are actually measuring

tritium in the environment, in the food and the air and the water, and the only thing that would be in the category of a prediction is assumptions about how much water people drink and so forth.

Q. And that brings me to the other reason for the difference, which is that you have counted the tritium ingested or inhaled for the immediate neighbours, i.e., 25 to 30 kilometres around the plant and not any further than that; is that right?

A. Well, it wasn't a hard rule of 25 or 30 kilometres. It was estimating the, what is called, local dose out to the point at which the dose would be 1 per cent of the dose received by the so-called boundary fence exposure, which is already 1 per cent or so of the dose limit.

So we are calculating to a cutoff, if you want to call it that, of about 10 to the minus 4 of the dose limit.

Now it is true that low levels of activity will -- because tritium has a 12-year half time, will migrate out that region. But I think it is not a particularly good nuclide to use to illustrate that concept, because there is such a large sink for water in the environment that migration - this is really an environmental question - but migration isn't

the same as it would for a Noble gas, for example.

We talked with Dr. Connell much earlier about some of the Noble gases, and the concern that some of them and some of the daughters are relatively long lived. I think that's a different kind of situation from tritium.

Actually, if I can take this opportunity, when we were talking about I think I gave you an incomplete answer. You were concerned about I think why we weren't concerned about the very long lived Progeny daughters of some of those short-lived Noble gases. I think the answer of course is that the Noble gases are producing roughly equal yield, molecular yield, and if they decay in say nine hours, which was the case with xenon 135, to a daughter which has a two-and-a-half million year life, then the specific activity which is the decays per unit time must be 7 orders of magnitude less for the long-lived progeny.

Anyway, that was an aside to correct something that I failed to do earlier.

Q. Now, in answering your question you just made reference again to the amount you are allowed to emit versus what you actually do emit. As I understand it, you try to keep your emissions at 1 per cent of the AECB's derived emission limits; is that

right?

So in other words, you theoretically could emit 100 per cent of the number called the derived emission limit?

A. Well, we have a target of 1 per cent, and as I am sure you are aware in the licence these numbers are referred to, so I don't think it would be likely that we would be allowed to emit at 100 per cent. There are certain actions which must follow if we exceed the 1 per cent.

Q. All right. And just to look at what the derived emission limit is, compared to the amount of tritium that you actually have in the reactor, or you might conceivably have. If I look at page 130 of the Exhibit 597, that table, as I understand it, is a statement of what the derived emission limits are by radionuclide emission category, and that's your current standard; is that right?

A. Generally, yes. They certainly were as of January 24th, but the Pickering DELs are being revised at the moment and I don't know whether they have been approved or not.

Q. If we use this number for the moment, then, as I look at this table, and if you add the air and water --

THE CHAIRMAN: This table, has it got a reference anywhere? It a seems to be attached to a letter of January 24th, 1992 from Mr. Gillespie to Mr. Rubin. Is it an response to an interrogatory or what is it?

MS. McCLENAGHAN: Yes. Thank you, Mr. Chairman. it's a revision to a response to Interrogatory 2.2.8.

THE CHAIRMAN: Which has already got a number, I believe.

MS. McCLENAGHAN: Yes.

THE CHAIRMAN: So it's number what?

THE REGISTRAR: .93.

THE CHAIRMAN: .93, thank you.

MS. McCLENAGHAN: Q. Now, that table gives amounts, derives emission limits on the basis of a period of a week or a month as the case is, and if you add the derived emission limits permitted for tritium to air and tritium to water and multiply those by the 52 weeks or the 12 months, respectively I calculate that you arrive at 155 million curies is what you are allowed to emit in a year; is that right?

DR. WHILLANS: A. Well, do you want me to check that now?

This was from one facility or all

facilities?

Q. This is from Darlington.

A. From Darlington. And just for tritiated water?

Q. And air. If you take both of them on an annual basis.

A. But only tritiated water to air?

Q. Yes.

A. Okay. So I take it you do want me to check this now?

Q. Well, maybe we can make it subject to check. But does that number sound like -- if you are looking at the 1.1 times 10 to the 5th for H(2)O to air per week and 1.2 times 10 to the 7 for H(2)O to water per month.

A. I think you are number is small; isn't it? Because just the water alone is 1.2 times 10 to the 7 times 12, which gets it up to 1.4-something times to the 8, and you said 10 to the 6th, I believe.

Q. No, 155 million or 1.5 times 10 to the 8th.

A. Yes, so that looks reasonable.

Q. And then if we look at what your evidence was earlier this morning as far as the amount of tritium that you had at Darlington, or could

conceivably have at the very most, you said that in the four units of the heat transport system there were 31.2 million curies.

MR. KING: A. I have done some calculations over the break and I think I have some numbers which are more in tune with what you were looking for.

You were looking for a total for both systems. So, for Darlington, for both moderator and heat transport systems, for four units, at the end of 40 years with no TRF working, the number would be 126 million curies.

With the TRF working, it would be 4.1 million curies. And I think that the value with the TRF working should be the value that is used in any calculation.

Q. All right. My question, though, is to compare the amount we arrived at as being the derived emission limit for one year at Darlington, which was 155 million curies.

DR. WHILLANS: A. Yes.

Q. And to compare that, to it looks like the most you could ever have at Darlington for 40 years without the TRF working is 126 million curies.

A. Yes.

Q. So there is obviously no way you can ever reach this limit.

A. I think you should understand, I am sure you do, that the derived emission limits are based on potential risk to the public, dose to the public, and don't refer back to how much is available for release.

So it's not surprising if the numbers don't match. For example, this Darlington DEL applies now, and the activity at Darlington is much less than the numbers Mr. King just gave.

So they are a separate thing. They are a calculation which show what kinds of releases would be acceptable if you assumed that a certain level of exposure or risk to the public is acceptable.

And I accept your numbers, that we couldn't release them at the moment.

[12:05 p.m.]

Q. Just to conclude this point, Dr. Whillans, when there is reference made then to the emissions being at less than 1 per cent of the limit, of the derived emission limit, whether it's routine or by spill, you are talking about a number that is less than 1 per cent of the number you can't reach. You don't have that amount of stuff to emit that much; is

that right?

A. At Darlington at the moment that seems to be true, yes. Subject to check on the numbers of course.

Q. Dr. Whillans, you commented earlier in the hearing in Volume 126 at page 22051 about the biological half life of tritium oxide or tritiated water and said it was about --

THE CHAIRMAN: Give me the page again, please.

MS. McCLENAGHAN: 22051.

Q. And you said that that biological half life was about ten days. Is that....

DR. WHILLANS: A. In an adult, yes.

Q. As I understand it, this means that you are assuming that half of any ingested or inhaled quantity of tritiated water has been flushed out of the body by 10 days after it was initially taken in?

A. Yes, that's generally the idea. Of course that is an average and particularly for tritiated water it's quite variable. In the summer, for example, people are drinking, have a large food intake, it will be shorter. It will be a little bit higher in the winter. It's different for different individuals. Well, the 90 per cent confidence

intervals on it go from about 5 to 14 days in adults males alone. So, it's a good rough number but it does vary.

Q. As I understand it, the committed effective dose equivalent conversion factor that Hydro uses takes that short biological half-life into account?

A. Well, the committed effective dose is a calculation which adds up the doses per unit time over the time that it is in the body. And so, as a reference number, just as a number we don't have other measurements, we would use the mean half time in the body. So yes, I agree.

Q. And just to clarify that, that is a mean; it could be longer it could be shorter?

A. Yes. As I said, it can vary by maybe a factor one-and-a-half or two.

Q. So if in a particular situation the tritium actually stayed in a person's body for twice as long as the number that you have used, the effect would in fact be that it was twice as toxic; is that fair?

A. Well, I guess I'm not sure whether we are talking about public dose calculations where we are making an estimate for doses that are, say, 1 per cent of background or something like that. In the work

place we don't make that assumption. We measure the activity where the levels are higher. We measure the activity weekly or bi-weekly and we calculate what the dose each day or each week is, and we don't make any assumption about the half time. And it comes out to a very similar thing. But as I said, there could be a factor of two different, so we do the more accurate method.

Q. But the particular point was that if the tritium did stay in a body twice as long, it would be twice as toxic?

A. That's true.

Q. Now in the hypothetical we looked at earlier, we calculated the population collective dose, an effect that we calculated, would have included only the toxic effect of the tritium for about two weeks; is that right?

A. Which number are we talking about now. Is it the person sieverts as a result of emissions, I guess, are they? And they are calculated on the basis of a ten-day half life for adults and a different half life for infants. So two weeks, it is not a strict cut-off. In ten days half of it has gone; in another ten days three-quarters of it has gone and so forth. You lose a half each ten days.

Q. All right. And I understand that although the biological mean half life is 14 days, the isotopic mean life would be about 17 years.

A. The radiological half-life of tritium is 12.3 years. So, the mean life is another term which is the half life divided by .69, so it's something a little bit bigger if you really mean the mean life. But the number we always talk about is the half life which is 12.3 years.

Q. Or the average would be higher?

A. Yes, okay. If you are using the term mean life, technically, yes, it's 1.4 times 12.3.

Q. So we have seen that you have taken into account in the calculations the biological half life, i.e., the first say two weeks or so, but those calculations and Hydro's report as to what the population dose is don't take account of the balance of that time at all, do they? So in other words, if in the first two weeks tritium has been absorbed and flushed away from a body, there is still radiated tritium going, for example, back into Lake Ontario and perhaps being taken up by somebody else somewhere else?

A. You are making the point that the tritium remains after it has passed through one individual and is available for other uptakes?

Q. Right.

A. Yes, that's certainly true. But the amount of tritium compared with the amount of water is so small that it's very unlikely.

Q. So, what it is that's making you assume you no longer have to worry about it is the amount of dilution?

A. Well, for example, we are checking over the break, I think, the comment that came from Dr. Connell. Even in the 33 per kilogram moderator water, something like 1 in 10 to the 6th hydrogen atoms is tritium, so even in that very high activity water there is a very, very trivial fraction of -- well, trivial in the sense of comparisons with the number of hydrogens that is actually tritium. And the concentrations in the environment are many orders of magnitude less.

So I am just saying that the tritium has not decayed to helium yet, but it's unlikely to have reached the first exposed person and it is that much more unlikely to be recycled into someone else.

Q. I would like to turn, Dr. Whillans, to your evidence at Volume 121, page 21229.

A. I have it.

Q. At the bottom of that page and over to the next, you stated or you told Ms. Harvie that the

measure of significance of exposure of populations from a societal point of view should be the total collective exposure integrated over the whole exposed population in units of person sieverts.

THE CHAIRMAN: What page are you reading from?

MS. McCLENAGHAN: Page 21229. The measure of significance from a societal point of view should be the total collective exposure integrated over the whole exposed population in units of person sieverts.

DR. WHILLANS: A. Yes, I said that and I agree with it. In this discussion we were talking about sort of a local context, but I wouldn't disagree that it's also important in a global context.

Q. In this discussion you mean the discussion we have just had this morning?

A. Right.

Q. As opposed to this evidence?

A. Yes.

Q. Yes. And your slide 39 set out, as I understand it, that total collective exposure, total population collective dose assessment from all Ontario Hydro activities?

A. Well, that's the distinction I was

just making. This is what you would probably call in an UNSCEAR context a local or regional -- a local, actually, collective dose. So, I didn't make the distinction here just for simplicity, but it isn't the total collective dose, I agree.

Q. So is there a significant difference between what the numbers in slide 39 would say if it was the total population collective dose assessment that you were showing as opposed to just the local?

A. Well, you are getting into an important but a very complicated area. And I would refer you to UNSCEAR, for example, as a place where all the complications are explored.

Certainly there are long-lived nuclides which we emit and which are not included in this calculation, and the kinds of complications are, for example, that we, as I said a few minutes ago, we calculate the doses out to the point where the individual dose is about one-ten thousandth of background or of the annual dose limit for similar numbers.

Beyond that is a great deal of uncertainty in the measurements because we can't detect some of these activities 1,000 miles away. Their importance in relation to other sources of those

activities, for example, tritium and carbon-14, are both produced in the upper atmosphere and the bulk of the world's source comes from those sources, not from Ontario Hydro or nuclear power generation.

Then, in addition, these are based on committed doses as you said. These are the doses that are received over time. And you showed us a table which went out to 10 million years. There is obviously concerns about how you calculate doses that will be received in 10 million years because these calculations necessarily depend on population densities, habits practices. Do we still eat vegetables, that sort of thing.

So I am just saying that this whole idea of total collective dose is one which is certainly considered by people who produce radionuclides and the answer to your question is, yes, that number would be bigger than the number I have shown here. But I didn't present it in this context for the reasons I have just given: that you have to look at it in quite a different perspective.

Q. So really slide 39, to be accurate, should have a big label across the top that says "local".

A. That would be accurate, yes. This is

the local collective dose assessment, by most definitions of local, which takes it out to a few hundred kilometres.

Q. Now wouldn't it be fair to say that it would be important to calculate the total collective population dose beyond the local area to find out what is the total impact, total harm that that activity might be causing?

A. Well, as I said, we certainly, we and the Atomic Energy Control Board, and ICRP and UNSCEAR certainly do consider these things. It's not just a simple extrapolation, as I think we were going through with your calculation of how many fatal cancers could have been caused if all of the tritium had been inhaled or ingested. Because you have to now take into account whether the tritium, for example, that goes into Lake Ontario will decay before it ever reaches another source of the population and whether some other nuclide that goes into the air will decay in the air before it's ever likely to have been inhaled by someone.

So there are a lot of other assumptions that have to go into those calculations, and we do do those but they are very uncertain and they generally result in numbers which, for individuals outside the local area, are so far below their background dose that

you have to really think about the context when you try to ascribe some kind of health effect to it.

Q. When you mention that you are taking into account the impact of the emissions, my understanding is that it's only the impact to humans that is being taken account of; is that right?

A. Well, I believe Mr. Johansen gave in his direct the ICRP view on this, which is that if you protect humans you will protect other species. Individuals and other species may be harmed if they happen to live at the outfall of the discharge, but whole species are not at risk.

Q. So other than that assumption that if humans aren't harmed other species won't be harmed, there is no other regulatory limit on emissions vis-a-vis any other species? It's just humans that are considered in these regulations?

A. I think you should ask Mr. Johansen if he wants to add to that.

MR. JOHANSEN: A. That's basically true.

Q. I would like to turn you to page 36 of Exhibit 597. And I take it this would be a document that you would be familiar with and a committee that you would be familiar with: The Advisory Committee on Radiological Protection of the AECB?

DR. WHILLANS: A. I am generally familiar with them, yes.

Q. And this particular document is November 1989 with an information No. 0340. And we have attached certain excerpts from that document in the following pages.

THE CHAIRMAN: Perhaps we should give this document a number then, exhibit number.

THE REGISTRAR: The exhibit number is 598.

THE CHAIRMAN: Thank you. We have already got a 598.

THE REGISTRAR: 599.

MS. McCLENAGHAN: Thank you.

---EXHIBIT NO. 599: Document from The Advisory Committee on Radiological Protection of the AECB, dated November 1989, with information No. 0340 thereon.

MS. McCLENAGHAN: Q. Now, I take it that you would agree with the very first sentence in the document at page 1 that:

"The major goal of radiation protection in Canada is to ensure that individuals, their progeny, and mankind as a whole are adequately protected against the harm that might arise from

unwarranted exposure to ionizing radiation."

DR. WHILLANS: A. I would agree with that.

Q. And the next paragraph says, and would you agree with this, that:

"Exposure to low doses of ionizing radiation at low dose rates is assumed to increase the incidence of fatal cancers and genetic disorders in the human population by a small fraction which increases in direct proportion to the total radiation dose."

A. Yes, I agree. I take it by a small fraction that means of the normal incidence...? Yes, I think that's what it means and I do agree.

Q. All right. And this document on page 5 contains a statement that I believe you --

A. This is page 5 of your exhibit?

Q. Sorry. Page 38 of the exhibit is page 5 of the document.

A. Sorry.

Q. And I believe you have testified earlier and would agree that there is an assumption

that there is linearity between the dose and the cancer risk?

A. Well, I believe what I said was that from the evidence that's available to date on human populations, one cannot demonstrate a threshold, for example, cannot demonstrate anything statistically stronger than a linear response for solid cancers.

There are certainly people who believe that the response should be stronger than that; that is, that the linear response under-estimates the dose. I think that might be the position of your client.

There are certainly people on the other side who believe that low doses of radiation are protective. This is the general area of hormesis, and I think my view of that is that it is another theory. There is no conclusive evidence to demonstrate it. But it isn't something which is just postulated by fringe scientists.

[12:30 p.m.]

The idea that low doses will stimulate repair mechanisms is quite a credible biological mechanism, and there have been large international conferences and recent books describing this sort of thing.

So I guess what I am saying is there is a

balance. And what the ICRP and Ontario Hydro accept is that the linear no-threshold response is a reasonable basis and probably conservative in the sense that we will assume there is harm attached to every exposure no matter how low.

Q. And would you also agree, as this document states, that that's the hypothesis that best fits the evidence that's available?

A. What sort of evidence are we talking about here?

You are referring specifically to the first paragraph on page 38?

Q. Yes. They say the presumptive -- four lines down: The presumptive evidence in favour of linearity includes, and then they set out three points.

A. Well, given that this is a 1989 document and this a very rapidly changing field, I don't really disagree with this. I guess I should point out, in fairness, that when we are talking about dose response, we are not talking about the .01 millisieverts as a result of a tritium emission in isolation. It's .01 on top of the 3 millisieverts of background.

So we are not talking about the very end of the dose response curve; we are talking about a

region which is in the low region compared with high dose exposures in the bombings in Japan, but still not at zero, I agree.

Q. I should just refer you to page 56, or page 45 in our exhibit, which lists the members of the Advisory Committee on Radiological Protection, the Working Group on Basic Objectives of Radiation Protection, and I take it that some of those individuals you would be familiar with; is that right?

A. Yes. This is the working group, not the whole Advisory Committee, and I am familiar with some of those people, yes.

Q. And some of them, for example, Mr. Newcombe, Mr. Myers, Mr. Marko, are from AECL; is that right?

A. Dr. Marko has retired, Dr. Newcombe has long retired, and Dr. Myers is retired, but they all did at one time work at AECL, yes.

Q. Now, I would like to refer you to page 39 of the exhibit, and particularly the statement contained there, about six lines from the bottom, where it says, following footnote 20, that:

> Reduction of individual doses is not the only goal. More important is the reduction of collective dose.

Would you agree with that?

A. Well, I think this follows from what we have just been saying, that if we assume a linear response, then small doses to a large number of people carry the same weight as larger doses to a smaller number of people, if the total collective dose is equal.

Q. So that's why collective dose reduction is important?

A. It is important, yes.

When they say more important, I think it should be in the context that I just mentioned, we would look at the total collective dose and we would not want to take actions which reduce individual -- put a large increase on the collective dose.

Q. Now, this is in the context of a topic called ALARA at this particular page, which I understand stands for as low as reasonably achievable, and I think you have talked about that before in this hearing. I understand that that process or that analysis as stated on page 14 amounts to - or page 40 of the exhibit, pardon me - amounts to a cost/benefit analysis. In other words, what trade-offs should be made in reducing collective doses; is that fair?

A. I think that is fair.

The full phrase is usually as low as reasonably achievable, social and economic costs being taken into account, factors being taken into account.

And yes, I think in my direct evidence I talked about the ICRP system which was based on justification, optimization and individual limits, and optimization is a cost/benefit process and that's where ALARA fits in.

Q. Right. And that's the approach that in fact Ontario Hydro does take in assessing whether there should be abatement or a reduction of collective population doses; is that right?

A. I think generally, yes. As you may well be aware, there are problems when you get into the details of what costs should be assigned, and if we moving on to the ALARA process, there is an ACRP report on that as well, there are social factors which are very hard to estimate, effects on perceived risk and things like that.

So what I am saying is that we do take it into account. It's not a matter of being sort of accountants and putting down so much dollars on one side and so many on the other and deciding whether it's a beneficial activity. I think we have to apply judgment. But we do use it, yes, certainly.

Q. Now, continuing on page 40 of the exhibit, under the topic collective dose commitment, a statement is made in the second paragraph under that topic:

> That human activities involving the production of radioactive materials with long half lives necessitate consideration of the potential health effects of radiation received from these materials in the future. This consideration is of particular importance in the management of radioactive wastes.
>
> The term collective dose commitment is used to define the collective radiation dose to all persons summed over the whole earth and all time.

And would you agree with the statement that's there?

A. Yes, I would agree.

Q. Then it continues in the next paragraph to say that:

> If the assumption of a non-threshold dose response relationship for radiation effects is correct, a summation over all time and space is necessarily involved in

the balancing of a given units of social benefit against the collective harm associated with the production of that unit of benefit.

Would you agree with it to that point?

A. Generally, yes.

Q. They say:

Given our present state of knowledge it is generally not possible to sum collective benefits to humanity from a given current practice over all time and space.

And do you agree with that?

A. Over all time and space, yes, I agree with that.

Q. Then at the end of the paragraph it says:

For those reasons it seems practical and realistic to establish appropriate cut-offs in the summation process.

And I think you were talking that earlier today.

A. Yes.

Q. Now, it goes on to say here that:

A cut-off or integration limit in a

summation over space is generally regarded as acceptable, provided the distance to the cut-off is sufficient to ensure that the true summation to the total global population is not grossly underestimated.

Would you accept that as a fair statement?

A. Yes.

Q. And then it goes on to say:

For example, a summation of doses from airborne releases of short-lived radionuclides such as radon 222 with a half life of 3.8 days to the boundary of Canada plus continental USA would not seriously underestimate the collective dose to the population of the earth.

Is that fair?

A. Yes.

Q. It says:

The same procedure might understatement global doses by a larger factor in the case of airborne releases of long-lived radionuclides such as carbon-14 with a half life of 57,030 and

30 years.

Is that fair?

A. Yes.

Q. A then it says:

In the latter case, i.e., carbon-14, the collective dose would be more appropriately summed for the whole population of the earth.

Is that fair?

A. Yes, that's fair.

Q. And then it goes on to give some examples.

The next paragraph states that:

The choice of cut-off for the corresponding summations over time represents a more difficult problem especially for those nuclides with very long half lives.

I take it you would agree with that.

A. Yes.

Q. Then it's speaking of alternatives at A, B and C, about how to take account of the difficulty regarding time, and it states:

(A) that there are those who favour short-term summation only, for example,

over something like 100 years as representing the foreseeable future.

A. Yes. The sentence you left out, I think, if we are going to use the ACRP report, you should see this one as well.

There is almost universal mistrust of the practical significance of results from theoretical calculations of dose commitments and harm commitments extending millions of years into a distant future, it becomes increasingly unforeseeable with advancing time.

I think that is a better stated way of stating what I said earlier, that you get very quickly beyond the period of, say, 100 years, into situations where it's very difficult to make predictions about some of the very key assumptions. And so that is why their statement A comes.

Q. So it goes on to speak about what the alternatives are to calculating the results over the millions of years; right?

A. This is paragraph B?

Q. Yes, A, B and C are all alternatives to calculating it over millions of years, is that --

A. That's right.

Q. So it's saying some favour short-term summation, something like 100 years. Would you agree that that's short-term summation?

A. I believe the number that has been variously recommended by the AECB is 100, UNSCEAR suggests something like 100 or sometimes 500. But they are all in the range of say 1- to 500 years.

Now, when it says others favours periods like 10,000 years, that's certainly the kind of number or even a larger number that is used by groups such as your client, I guess, but also by groups such as UNSCEAR in a particular context. And as long as you keep in perspective what the context is, I don't think there is any problem in using numbers like that.

Q. Numbers like 10,000 years?

A. That's right.

There are certainly some things that we can say with some certainly about periods out to 10,000 years. I don't think anybody would doubt that the half life of carbon-14 is not going to change over 10,000 years, but the other assumptions about practices and population distributions and so forth become very, very difficult to predict. And also the importance of certain measures of harm are very hard to predict in 10,000 years. If we are talking about, for instance,

your calculation about fatal cancers, I don't think we know what the likelihood that fatal cancer is going to be serious is in 10,000 years.

Q. The paragraph following A, B and C makes the statement that:

> The importance of ALARA would be downgraded if no attempt were made to estimate the potential collective dose commitment summed over all space and time which might result from the production of a given unit of collective benefit.

And it goes on to say:

> The estimate can be valuable, for example, in attempting to decide which of the various options available might be logically selected for the management of long-lived radioactive wastes.

And I take it you would agree with that statement?

A. I would agree. I don't know whether you want a comment from Mr. Johansen as well.

Q. Mr. Johansen, do you have any problem with that?

MR. JOHANSEN: A. No, no problem.

DR. WHILLANS: A. We did again stop just

before another important sentence which was:

> That the practical value of the summation could become invalid if too much weight were given to extremely uncertain dose contributions in the distant future.

I think that's what I am trying to point out.

Q. Yes. And then it goes on to say:

> Predictions over tens, hundreds or even thousands of years may be useful guides as to consequences of present actions, but predictions over hundreds of thousands or millions of years are generally considered to be of very little practical relevance.

A. Yes, that's from a particular reference, but I think that's generally fair.

Q. In page 42 of the exhibit, the third paragraph down, this is under the topic the de minimis concept, and I think that's what you were talking about earlier. It says:

> The collective dose resulting from dispersal of small amounts of long-lived radionuclides in the biosphere might be

considered too large to be negligible from a societal point view, even if dose rates to individuals were very low. For this reason de minimis collective dose rates should also be considered. Thus, a given source could not be considered de minimis unless it met both the individual and collective dose rate criteria.

Is that a statement that you can agree with?

A. I can agree with that.

Q. And then the next paragraph says:

Some of the other factors to be considered in establishing de minimis values for collective dose rates include the possibility of large numbers of activities in many countries around the world, each resulting in very small doses to people in Canada. Moreover, doses from continued releases of long-lived radionuclides such as carbon-14 would be cumulative.

And I take it you would agree with that too.

A. Yes, yes.

Q. And then finally the paragraph at the end of this topic says:

> One of the main objectives of radiation protection is to ensure that the collective harm to society from a given activity will be a small as possible in comparison with the collective benefit.

I think we talked about that as being ALARA.

It says:

> Where a collective dose can be reduced cheaply and in a cost-effective manner, this should be done regardless of whether or not that does exceeds a de minimis criterion.

Would you agree with that?

A. I think generally, yes.

There is obviously a value judgment alluded to here, cheaply, but as a principle, I don't disagree.

Q. Now, I would like to turn to page 47 of the exhibit, which is an excerpt from your Exhibit 507. And at bottom of page 47, under the topic Local and Regional Collective Dose, it is stated:

The dose received by a population is of more interest in this section as it provides a measure of the collective impact of the source of radiation exposure.

And you told us a few minutes ago that the slide on page 46, your slide 39, is really a local population collective dose assessment slide.

A. Right. I am just trying to be careful here because we have been talking about the importance of, sort of, global collective dose, but they are really saying collective dose.

In the context of Exhibit 507 and my direct evidence, I was using collective dose correctly, but it was a local collective dose. So we are talking a little bit about the different things but the principle is the same, yes.

Q. So, for example, at page 48 of the exhibit, the report states that the population collective dose value used in the report is taken -- first of all at it references a study, Ontario Hydro 1991E, from which this information was taken.

A. I believe that is one of our exhibits.

Q. Yes. And it's also attached at page

55 of this exhibit.

A. That's correct.

Q. And so at page 48 it mentions that:

The population dose in the study for airborne tritium and Noble gas emissions is calculated out to a distance from each reactor site... which you told us about before. ...at which individual dose or exposure is 1 per cent of that at the boundary.

A. That's correct.

Q. Then it goes on to say for Pickering, Darlington and Bruce this is about 30 kilometres from the stations.

A. For the airborne, that's correct, yes.

Q. And then population collective dose for emissions to water, a couple of sentences later, is calculated using the population served by water supply plants within a 25 kilometre radius of each site, and that's what is been used in preparing your evidence about population dose?

A. Yes.

Q. And then you go on to, or in the exhibit it goes on to state that:

It is possible to calculate for long-lived and mobile radionuclides a regional and global collective dose assessment and to integrate those doses for future times. However, the individual doses that would be calculated are highly uncertain and exceedingly small and the additional implied risk would be below any meaningful quantity.

Is it that something you agree with?

A. Well, I agree subject to noting that in this particular part of the presentation they are trying to give perspective on individual risks and not really making a comment on collective dose or collective risk.

I am just saying that we are talking here about calculating doses out to the point where the individual doses are quite small and become uncertain.

Other parts of this document and certainly other Hydro documents talk about the collective dose aspect.

Q. I read your slide 39 as saying total population collective dose assessment.

[12:47 p.m.]

A. Well, we agreed that that was a total

local--

Q. Local.

A. --population collective dose assessment, yes.

Q. Am I right in understanding that the local dose assessment that you have set out in slide 39, and that you describe on page 47 of this exhibit, and 48, is a reflection of your or Ontario Hydro's estimate of the appropriate cut-offs under which they are measuring most of, or almost all of, the population dose effect?

A. I don't think it said the cut-offs were necessarily measuring all of the population dose effect. Maybe we should refer back to where that was stated. But I think the point is that for the purpose of estimating local impact, these cut-offs are believed to be appropriate and they are not numbers that Hydro has derived; they are recommendations on cut-offs from ICRP, from UNSCEAR and from the AECB and we apply them.

Q. So these numbers and what Ontario Hydro does, does not measure and you aren't stating here what the population collective dose assessment is from Ontario Hydro activities? You are saying, you are just showing what the individual risk within a very specific geographical area is?

A. In this report that is what we are stating there. We also provide, for example, numbers to UNSCEAR. And in UNSCEAR there are many pages of discussion about collective dose to world populations, say from carbon-14, nuclear power generation, and there will be numbers for heavy water reactors and so forth.

That kind of evidence, that integrated evidence is based on information that we and other groups provide to them. And I think if we refer to that report, for example, we can see the other side of the impact of our emissions.

Q. Was that part of your direct evidence?

A. I didn't present any information from UNSCEAR, to my knowledge.

Q. So, no information on global population collective dose assessment was presented in your direct evidence?

A. I don't think so, no.

Q. Now beginning at page 55 is the report that was referenced a moment ago in your exhibit 507 I believe.

A. Yes. Well, the interrogatory number is shown above. It was provided in response to an interrogatory.

Q. Interrogatory 9.17.36.

A. 36, I think, yes.

THE REGISTRAR: That is 520.15.

MS. McCLENAGHAN: Thank you.

Q. So this report that we are now looking at is the report containing information from which Exhibit 507 was prepared in this context; is that right?

A. Well, 507 drew information from a number of sources.

Q. Sure.

A. And this is one of the annual summaries which contributed information, yes.

Q. Then again on page 56 of this exhibit under the topic "Population Collective Dose Assessment", it says the population collective dose is the sum of all the individual doses received by a subject population. Is that right?

A. That's correct.

Q. But that's --

A. That statement stands on its own. Now I think you have been questioning whether what I called on my overhead Collective Dose was really a local collective dose and I agree that it was.

Q. Right. And you applied a cut-off

within an area of the Ontario Hydro stations that you were looking at?

A. That's right. The cut-off was applied based on fractions of maximum dose, and that's a little different criterion, for example, from what UNSCEAR calls a local dose. I think they give you distances out to a few hundred kilometres. There would not have been any significant additional dose on that region in our numbers the collective dose would have been very similar.

Q. But if you did it on a global basis, would it --

A. On a global basis would be a different number, yes.

Mr. Johansen was -- maybe you are heading that way, but he was referring me to the statement on page 57 opposite:

> "Again, global collective dose assessments could be made, but the additional individual doses that would be summed beyond the present cutoff would be well below any meaningful quantity in terms of health risk."

Individual health risk.

Q. Right. But what about the concept of

collective population dose that we were looking at earlier in the AECB regulatory working group study?

A. Yes, that is important, I agree.

Q. But that's not what they are talking about here?

A. It's not in this report, no.

Q. I think you should recognize the importance of this annual summary is to document in one place for presentation for review by the AECB for example but also for public information all the environmental and emissions measurements over that year from all the stations, and it's essentially a set of tables with a bit of commentary about significance and it doesn't represent, you know, the entire body of information that Hydro has on collective dose.

Q. You know, on page 57 under the topic Airborne C(14) Emissions, firstly the statement is contained that:

> "Only the population collective dose due to consumption of food grown in the vicinity of the nuclear stations is considered."

I take it that's accurate?

A. I assume so, yes.

Q. And then it says towards the end of

the paragraph, just before the statement you just read to us:

"As with the calculation of population collective dose from airborne emissions, the integration cutoff ignores any possible wider area or global impact."

Again global collective dose assessments could be made and you read us that. So that's accurate, is it?

A. Sorry, I was having trouble finding it but I have it now.

Q. Just after footnote 6.

A. Yes. Okay, yes.

Q. And I see from the middle of the paragraph that the area being considered with respect to the consumption of food grown in the vicinity of nuclear stations is apparently Pickering 10 kilometres and Bruce 5 kilometres and Darlington is assumed to be the same as Pickering?

A. Yes, in the previous sentence it talked about how those numbers were arrived at.

Q. And so you are saying --

A. I think if we are going to talk about the carbon-14 dose calculation we should probably read the whole paragraph and in the order in which it flows.

But basically these are the numbers, yes, and there is a reason why they were picked.

Q. And what is that?

A. Well, then, let's read it. I will start back:

"Thus the population collective dose may be calculated by multiplying the total excess carbon-14 content of the food by the dose conversion factor. The total excess carbon-14 is obtained by integrating the excess carbon-14 content of food produced in the area from the boundary fence out to a distance at which an individual consuming all of his food requirements from food grown at that location would receive an annual dose of 1 microsievert from excess carbon-14."

Compare that with the 3 millisievert background.

"The carbon-14 specific activity corresponding to this dose is 100 becquerels per kilogram of carbon above background. The corresponding distances for this specific activity are: Pickering, 10 kilometres; BNPD, 5

kilometres. Darlington is assumed to be the same as Pickering."

And so forth.

THE CHAIRMAN: Sorry, are you reading from --

DR. WHILLANS: I'm sorry. I'm reading from the earlier part of the same paragraph, 7.2.2 on page 57.

THE CHAIRMAN: I have got it.

DR. WHILLANS: And I was just trying to give -- well, I think I was asked something about how these numbers were arrived at and I was trying to give the full context here.

THE CHAIRMAN: Okay.

DR. WHILLANS: So basically the cut-offs were developed from a dose of one microsievert to an individual.

MS. McCLENAGHAN: I would like to turn you to page --

THE CHAIRMAN: Are you going on to something else?

MS. McCLENAGHAN: This would be an appropriate time for a break, Mr. Chairman.

THE CHAIRMAN: We will break now until 2:30.

---Luncheon recess at 12:57 p.m.

---On resuming at 2:34 p.m

THE REGISTRAR: This hearing is again in session. Be seated, please.

THE CHAIRMAN: Ms. McClenaghan.

MS. McCLENAGHAN: Mr. Chairman, before I start, it occurred to me over the break that I neglected to introduce Mr. Rubin, who is sitting beside me during this cross-examination.

THE CHAIRMAN: I hesitate to say that Mr. Rubin needs no introduction, so I perhaps didn't say it, but it will no doubt will appear on the record.

DR. CONNELL: I wonder if I might just interpolate a question that is related to some of the discussion we had this morning directed to Dr. Whillans. I am thinking of the tritium emissions question, Dr. Whillans, and I just put it to you whether this approach might shed some light on it.

If you consider the natural occurrence of tritium, I think it is probably safe to assume that most of the world's supply would be in water. Do you agree with that?

DR. WHILLANS: I think that's correct.

DR. CONNELL: That would far outweigh, say, the hydrocarbons and other major reservoirs?

DR. WHILLANS: Perhaps I am not qualified to comment. That's my impression, but do you have another view?

MR. JOHANSEN: No.

DR. WHILLANS: Subject to check, that's right.

DR. CONNELL: Anyway at least insofar as the reservoirs which are reasonably freely equilibrated, I think water must be the dominant one.

DR. WHILLANS: I think so.

DR. CONNELL: Then I think we can also assume that there is a steady state level of tritium in the global water supply and that steady state would be the resultant of the rate of decay, that 12.3 year half life, and the rate of generation of tritium by whatever means.

DR. WHILLANS: Right. In the upper atmosphere.

DR. CONNELL: Yes. So if you make an assumption of so much water in the globe and so much tritium as a constituent, as a constant fraction of that water, then if you start before there were any heavy water nuclear generating plants and if you imagine that the rate of production of tritium would have increased to a very small extent because of the

plants that Ontario Hydro has put in place, and because now you have stepped up the rate of production just slightly, presumably the steady state level of tritium would be a little bit higher than it would have been in the pre-nuclear age. Are you following me so far?

DR. WHILLANS: I'm not exactly sure where you are going, but I think I am following you, yes.

DR. CONNELL: Well, I will just leave this with you as a question: Do you think it would be informative - I expect it would be quite a simple matter to calculate that increment in the steady state and I think you have given us enough data this morning to do it - whether it would be illuminating to know the degree to which the global tritium level has increased as a result of Hydro's contribution to it.

I think this may be an alternative way to explore the kinds of questions that Ms. McClenaghan was pointing to; that is, when the tritium get very widely diluted, as it undoubtedly would on passing through one or more organisms and passing into the waters of Lake Ontario and so on, that it seems to me unproductive to try to trace pulses of tritium in that way and imagine any effects that they might have.

But if you could just look at the entire biosphere and say globally the increment as being .001

per cent or what have you in the natural abundance as a result of the newly established steady state, that it might be illuminating -- on the other hand it might not.

DR. WHILLANS: I agree that might be helpful. It's true for tritium and also for carbon-14 that the world supply is not a result of nuclear activities and -- well, I should let her agree or not that it would be useful.

But I think the concern that people sometimes have is that although there is a total world inventory of tritium, the stuff that's at the bottom of the oceans is not actually available to the same extent as surface waters and so forth, so you have to take into account some of these other subtleties. But certainly the simple calculation of the total inventory of tritium in comparison with what has been produced by nuclear generation would be a useful subject to that kind of comment.

And the same applies to carbon as well. We talked quite a lot this morning about -- I guess we were talking about whether we adequately take into account the global implications of carbon-14 and we talked a bit about how UNSCEAR tries do this. I was also going to refer to an NCRP report No. 81 called

Carbon-14 in the Environment, where it points out that the carbon-14 exposure of the world's population, only 1 per cent of that is due to all nuclear generation. And there are other sources which quite outweigh it even for specific nuclides; and although it is important that we be responsible for all the activity we disperse, I think we do have to keep it in context.

MS. McCLENAGHAN: Q. if you are going to provide that information, I would request that you provide that information for carbon-14 as well.

DR. WHILLANS: A. That was carbon-14 that I just mentioned, yes.

Q. So you are saying it is 1 per cent for all...

A. This is not an exhibit so I don't know whether it's reasonable to reference it. But this is report No. 81 in the NCRP series. It's dated 1985 and it's called Carbon-14 in the Environment.

Well, for example, there is a graph on page 66 which gives the total carbon-14 dose of those from fallout and those from nuclear power on a five-log scale and shows that for the foreseeable future nuclear power will contribute no more than 1 per cent even to the carbon-14 doses.

And on page 65 it says the dose to human

beings from carbon-14 will be insignificant for the foreseeable future. The contribution from fallout will continue to decrease with time and that from nuclear power production will increase, but will remain at a level 2 orders of magnitude less than that from naturally produced carbon-14.

So as I say while I think it is important, and especially when we are not talking only about carbon-14 but other long-lived nuclides, to be responsible, I think we do have to keep it in context that there are other sources of even that nuclide which far outweigh reactor generation.

Q. I think, if I'm correct, Dr. Connell's question was directed to how much the Ontario Hydro generating plants increase --

A. That's to the world's inventory.

Q. Yes.

A. And you would like that number for tritium and for carbon-14?

Q. Yes, because I take it that you would be able to advise if you are using the 1 per cent figure from the reference you just gave as to what proportion of that 1 per cent is due to CANDU nuclear generation as opposed to other kinds of nuclear generation.

A. We can certainly get that number if you like.

MR. B. CAMPBELL: I think we better have an undertaking number so we can find it.

THE REGISTRAR: That would be 532.9.

THE CHAIRMAN: 532.9.

---UNDERTAKING NO. 532.9: Ontario Hydro undertakes to provide what proportion of the 1 per cent from report No. 81 in the NCRP series, dated 1985, Carbon-14 in the Environment, page 66, is due to CANDU nuclear generation as opposed to other kinds of nuclear generation.

MS. McCLENAGHAN: Q. Dr. Whillans, I would like to turn you now to page 62 of our Exhibit 597, which are excerpts from the Select Committee on Ontario Hydro Affairs, 1980.

THE CHAIRMAN: Do you know whether this document is already an exhibit?

MS. McCLENAGHAN: We did look, Mr. Chairman. I thought it was but we didn't find an exhibit number for it. So maybe Mr. ....

THE CHAIRMAN: There is a reference to Interrogatory 2.4.2. Has that got any significance as written on that?

MS. McCLENAGHAN: No, that is not significant here, Mr. Chairman.

THE CHAIRMAN: Then perhaps we should

give this an exhibit number then.

THE REGISTRAR: This will be 600.

---EXHIBIT NO. 600: Excerpts from the Select Committee on Ontario Hydro Affairs, 1980.

THE CHAIRMAN: Thank you.

MS. McCLENAGHAN: Q. And of course, Dr. Whillans, you would be familiar with this report?

DR. WHILLANS: A. I have read the excerpts that you have provided. I haven't recently read the whole report, no.

Q. The first excerpt that we provided is at page 62 of the main Exhibit 597 and it contains a statement that the routine emissions from nuclear reactors include a number of different elements.

[2:45 p.m.]

Two are of special interest to the committee, carbon-14 and tritium.

In the second paragraph it states:

> Carbon-14 and tritium are of comparable and special concern for similar reasons. First, they each have long half lives, 5,730 years carbon-14, and 12.3 years for tritium. Long half lives allow them to accumulate in the environment around a reactor and in the

global biosphere. Secondly, they are easily incorporated into human tissue. Carbon-14 is incorporated into the carbon that comprises about 18 per cent of total body weight including the fatty tissue, proteins and DNA. Tritium is incorporated into all parts of the body that contain water. Thus, the radiological significance of both elements is not related to their inherent toxicity as each is a very low energy form of radiation, but the their easy incorporation in the body.

Would you agree with that statement?

A. I am not at all clear what was meant by the last sentence, the radiological significance is not related to their inherent toxicity. I just don't know what they meant by toxicity. The rest of it I certainly agree with.

Q. So you would agree with the statement that the radiological significance of both elements is related to their easy incorporation into the body--

A. Yes.

Q. --if we took that part of?

A. Yes. Because as we said earlier,

these particular nuclides are not what we call external hazards, the radiation, they don't have penetrating beta gamma radiation which makes them a hazard from outside the body.

Q. But once they are inside the body they are definitely a hazard?

A. That's right.

Q. On page 64 of the exhibit, the second paragraph there states:

> Carbon-14 is not just a problem of the most exposed individual, its long half life makes it a problem for the global environment.

And I think you said earlier --

A. Sorry. I have it now.

Q. All right. And would you agree with that?

A. The first two sentences?

Q. The first sentence in the second paragraph.

A. Yes.

Q. First two sentences.

A. Yes, I agree.

Q. And then two-thirds of the way in that page it states that:

The Committee is concerned that Canada and Ontario in particular may have a special global responsibility for controlling carbon-14 and tritium that goes beyond consideration of local effects.

I understand that as referenced earlier on the page, back up in the paragraph we just looked at, that's because, as it's stated, the nuclear power programs, they are concerned in nuclear power programs because their artificial production is a significant proportion of the natural production which will result in an increase in the global inventory of each nuclide.

A. You are asking if I agree?

Q. Yes.

A. Well, if by significant we mean sort of measurable, as we were just saying for both of these nuclides it's not a dominant fraction of total production, but it is significant, sure.

Q. And to shed some light on the figure that you are going to be getting for us pertaining to the last undertaking, that paragraph continues that:

The large scale atmospheric testing of nuclear weapons in the 50s did in fact result in large increases in the global

inventory. Since atmospheric testing ended global inventories in man's immediate environment have been declining as these elements seek into the deep oceans.

Would you agree with that?

A. Yes, that's true.

Q. And so when you provided us with the figures that you are going to provide us with, it will be reflecting background which includes this component of increases from nuclear weapons testing?

A. Yes. Well, we are talking about total inventory, but I should point out, the same is true of tritium. But for carbon-14 the total inventory is composed of many things, but fallout is not dominant either. It's more than nuclear power generation. Well, I guess in 1990, according to the figure I referred to in the NCRP report, it looks like about 10 percentage and nuclear power was about 1 per cent. So there is still a great deal more beyond those two things.

Q. Now, the final paragraph on page 64 states that:

The AECB, with its limited staff, accepts the recommendations of the

ICRP...

Which I understand is the International Committee on Radiation Protection?

A. Commission.

Q. Yes. And that the major Canadian role in standard setting has been to provide representatives, and in one case the chairman to that Commission from a AECL.

And so it says:

> The basic Canadian regulatory standards come from a body reputed to be dominated by those the critics call the nuclear establishment, manufacturers, utilities and regulators.

Is that a fair statement?

A. Well, there is a number of things I guess in that paragraph. One, I think you should know that the ACRP that we were talking about earlier has established a working group looking at long-lived radionuclides, so in that sense they are developing their own Canadian standards. And so this is one way they expand the effort they can provide with their limited staff.

Canada has certainly provided a number of representatives to the ICRP, and I guess -- they

haven't all been from AECL, as a matter of fact. And this is 1980. And I guess since it says reputed to be dominated by these people, I guess I can agree with that.

Q. The next page of the exhibit, page 65, contains some recommendations by the Select Committee, and particularly recommendation 3 was:

> That a council should be formed by the government of Ontario with given terms of reference and representation from within and outside the nuclear establishment to provide an institutional forum for public participation and a focus for concerns of radiation problems in Ontario, to build up Ontario-based technical knowledge and to oversee as much epidemiological work as is necessary to decide what the standards should be for health and safety for the people in Ontario.

Was a council like that set up to your knowledge or does a council like that exist?

A. No. To my knowledge we still depend on federal working groups.

Q. And it went on to say that:

> The council should review particular

problems of radiation associated with operating our plant reactors, independent of Ontario Hydro and the government.

So it would seem that that has not happened then.

A. Not to my knowledge.

Q. And they noted, finally recommendation 4:

One of the first tasks the council should take on and give high priority to is an independent review of the adequacy of current proposed release limits for carbon-14 and tritium, taking into account both local and global concerns.

And again it would seem that has not happened.

A. This is exactly what the ACRP working group No. 8 is doing. But it is not an Ontario group, I agree.

Q. So that is not an Ontario group. And they are working on that right now as we speak, is that what you are saying?

A. I am not sure as we speak, they are not all there. But yes, they are meeting over the last year or so and into the future.

One of the members on the group is Dr. Richard Osbourne of Chalk River who is also a member of ICRP, and so there are connections between international philosophical bases, I guess, and what this working group is working toward, I guess.

Q. And I gather from your comments that they are meeting on an ongoing basis, that they have haven't come to any conclusions or published any report or initiated any specific action as a result of any concerns about these issues?

A. From my memory, I think there have been three meetings over the last year or so, and in between what is being done is to review international literature and also to collect specifically from groups like Ontario Hydro information about emissions, so that they can be fed into the final report.

Q. All right. And in the 12 years since 1980, that's all that's happened to your knowledge about this issue?

A. Well, that's to my knowledge, but perhaps someone else would have another opinion.

MR. JOHANSEN: A. I have got nothing to add to that.

Q. Now, I would like to turn to page 73 of the exhibit, which is first of all an interrogatory,

No. 10.2.25.

THE REGISTRAR: That will be .94.

---EXHIBIT NO. 520.94: Interrogatory No. 10.2.25.

MS. McCLENAGHAN: Q. I notice in that interrogatory there is a reference under the response in the third paragraph to a study that was performed by the AECB on the cost-effectiveness of reduction in off-site dose from routine emissions. It was AEC Report INFO-0277.

DR. WHILLANS: A. Yes, I think that should be I-N-F-O. But that is correct.

Q. And although that report wasn't provided along with this interrogatory, we have included it in this exhibit beginning at page 74. And I take it this would be a report with which you are familiar?

A. I have read the excerpts that you provide.

Q. It's titled Cost-Effectiveness of Reduction of Off-site dose by Atlantic Nuclear Services Limited, and it's a research report prepared for the AECB in March of 1988. And I wonder, Mr. Chairman if this might have its own exhibit number.

THE CHAIRMAN: All right.

THE REGISTRAR: 601.

---EXHIBIT NO. 601: Cost-Effectiveness of Reduction of Off-site Dose, by Atlantic Nuclear Services Limited.

MS. McCLENAGHAN: Q. Has Ontario Hydro done its own study of this sort of topic, i.e., the cost-effectiveness of reducing the off-site doses?

DR. WHILLANS: A. For any particular nuclide or in general?

Q. In general.

A. I believe we have done some. But maybe Mr. Johansen could describe it.

MR. JOHANSEN: A. Yes. As a matter of fact, this is I guess you could call it an ongoing exercise. In conjunction with nuclear rehabilitation programs, for example, at Bruce "A", and Pickering, a number of options for reducing off-site emissions and dose effects are being considered, and they are being evaluated. They are using the kind of cost/benefit analysis that Atlantic Nuclear used for their study, for the AECB.

Q. I take it those studies are or documents haven't been provided to this point in your evidence, or in the response to this interrogatory or others?

DR. WHILLANS: A. In Exhibit 452 there was reference to the general kinds of additional

controls that are being considered. But I don't believe there was any detailed evidence and I don't think there is a final report on any of these.

Q. Now, the interrogatory response at page 73 indicated that the kinds of options that were considered in this study, the Atlantic Nuclear Services study, and it set out four and then indicated what the costs were. And stated that:

> The cost associated with reducing the routine emissions are expressed per unit dose averted and for the proposed options are typically in the order of a million to 10 million per person sievert dose averted. The level at which a dose reduction measure is considered reasonable and beneficial is on the order of $10,000 to $100,000 per person sievert dose averted. As such the results indicate that further dose reductions are not warranted.

First of all, do you agree with that statement in this interrogatory?

A. You are asking either of us in particular.

Q. Yes, either of you.

MR. JOHANSEN: A. Well, I guess I could start by indicating that the numbers, $10,000 to $100,000 per person sievert avoided or averted, that obviously is a somewhat subjective threshold. I don't think we should place an undue weight on that threshold.

The fact is that the emissions that we are talking here are already very low. We are typically talking about less than a per cent of the regulatory limit to the most exposed members of the public. But even so, we are not saying that that's the end of it, we won't worry about residual effects or do anything about them.

We do continue to look at the feasibility of improved control technology, and as that technology evolves, and as the need is assessed to require additional action, we would plan to do so. And that is what is generally reflected in the Update document, Exhibit 452.

DR. WHILLANS: A. These numbers, 10,000 to 100,000 are, typical of the values used in ALARA documents in several countries.

Q. Is it fair to say that as long as you have been meeting the 1 per cent of the regulatory limit requirement, that Ontario Hydro has not seen the

need to go beyond that in reducing the emissions?

A. I am not sure that's really true.

We have met the 1 per cent for tritium for many years and we could of still put in place the tritium removal facility. Now I agree to some extent that was to reduce occupational exposures, but it will also reduce tritium emissions to the environment.

Q. I would like to refer you to page 81 of the exhibit, which is a table 8, titled Liquid Effluent Treatment Methods, summary for Darlington.

I should note before we specifically examine that, that in the preface to this report on page 75, the authors stated under purpose of the report that:

> The report is intended only to assist in evaluating the technology options. No judgments are made nor are any opinions expressed on the cost/benefit of any technology.

Turning to page 81, that table indicates at the top that the total liquid emissions excluding tritium for Darlington without treatment are 70 gigabecquerels per year; is that accurate?

MR. JOHANSEN: A. That looks high in my view by comparison, for example, to the reported

emissions from Bruce "B".

Obviously you are talking about a reference value here since Darlington is not anywhere near full capacity. But even as a reference value, it appears considerably higher than the reported emission values for Bruce "B", which would be a comparable station.

Q. So what do you think the figure would be?

A. I will just --

DR. WHILLANS: A. It will be in our exhibit, won't it?

MR. JOHANSEN: A. To look back in this volume, to around page 18, which is the Atomic Energy Control Board's summary, of emission values reported by Ontario Hydro and other nuclear operators,

THE CHAIRMAN: Page 18 of the Atlantic Nuclear Services Limited Report.

MR. JOHANSEN: No. This, Mr. Chairman, I was referring to page 18 of Energy Probe's volume.

THE CHAIRMAN: Thank you.

MR. JOHANSEN: Which is Exhibit 597.

[3:05 p.m.]

And I am just searching now for the appropriate -- yes, on page 26, are the values from

1984 to 1988 liquid releases of tritium and gross beta activity from Bruce "B".

And if we look back to page 23, we are sort of jumping around here, but on page 23, you will find in tabular form the emission values for Bruce "B" gross beta in terabecquerels. And if you convert those, it looks to me like the average over that period is of the order of 10 gigabecquerels per annum as opposed to 70.

Q. So if the author of this report obtained the figure of 70 gigabecquerels per year from Ontario Hydro, then they obtained inaccurate information it would seem. Is that what it appears?

A. I am not sure where that number came from.

DR. WHILLANS: A. They wouldn't necessarily have obtained it from Ontario Hydro because these annual summaries are all in the public domain.

THE CHAIRMAN: Where do you derive your 10 from, Mr. Johansen?

MR. JOHANSEN: From page 23, Mr. Chairman.

THE CHAIRMAN: Yes?

MR. JOHANSEN: At the bottom right-hand corner is the table and four columns over or up,

depending on your orientation, there is a listing of so-called gross beta liquid effluents from Bruce "B".

THE CHAIRMAN: Yes.

MR. JOHANSEN: In terabecquerels and I simply moved the decimal place over three to arrive at something like --

THE CHAIRMAN: I am still trying to find the one. Where is it?

MR. JOHANSEN: I simply mentally averaged them out. It's not a precise number.

THE CHAIRMAN: What, the five figures that are shown there?

MR. JOHANSEN: Yes. That's just a rough number. I didn't actually work it out.

MS. McCLENAGHAN: All right.

THE CHAIRMAN: It's a lot less than 70 in any event?

MR. JOHANSEN: It is less than 70 obviously.

MS. McCLENAGHAN: Q. So for some reason the author of this report has used a much higher number and perhaps we will be able to examine that later.

I note that this report at page 81 outlines in the table certain treatment methods in the left-hand column. And the next column indicates what

the reduced annual emissions would be. And finally after the application parameters at Darlington, it indicates the annual 1987 cost in dollars.

And so, for example, the treatment method filtration is stated to reduce annual emissions and we have obviously got a problem here with the numbers. They say from 70 gigabecquerels per year to 38 gigabecquerels per year and that the annual cost of that is $3,000. Is that something that Ontario Hydro has examined the cost/benefit of doing and is that something that Ontario Hydro is doing?

MR. JOHANSEN: A. Well, that filtration is basically something that we are doing. We do have filtration and ion exchange equipment in our active liquid waste management systems, which we use, if necessary, to maintain our emissions below the annual or the operating target.

Q. At page 82 of this document, under the topic, "Current Liquid Effluent Treatment Practice", it mentions that several sites, Pickering Bruce and Point Lepreau 1 have filtration and/or ion exchange systems. Is that what you are talking about?

A. Yes.

Q. But it goes on to say but these are not being used to achieve emission limits substantially

less than 1 per cent of the derived emission limits. Do you agree with that?

A. That's another way of saying what I just said. We use them in order to control our emission levels below the operating target.

I should make a comment, however, on table 8. And it perhaps pertains to the rest of the report in general. And that is in the conclusion which is given on page 59 of the full report but which doesn't appear in this particular excerpt, the authors qualify their results with a number of cautions.

For example, they have two areas of caution which they set forth; one pertaining to the dose estimates or the estimate of actual collective dose savings and the other pertaining to the cost estimates.

With regards to costs estimates, they indicate their belief that the figures reported are within a factor of about 2, but with regards to the various local, regional and global dose estimates and therefore dose savings estimated, for a variety of reasons which they set out, they indicate that they may be over-estimating the potential dose savings by as much as 10 times.

So, I guess what I'm saying is that one

has to be pretty careful interpreting the values in tables like table 8 because there could be a swing of at least 10, possibly as much as 20 if you look at the cost/benefit ratio.

Q. So, if you are looking at table 8 with those assumptions then, the filtration cost of $3,000 could presumably be as little as $1,500 or as high as $6,000 per year.

A. That's how I would interpret their note, yes. I would also make the point that what they are giving here are cost estimates which are intended to apply to new plants and they have used Darlington as a reference for a large multi unit-plant.

You wouldn't be able to apply those sort of cost estimates, and I am sure that Mr. Penn could elaborate. You could not directly apply those sort of cost estimates in a retrofitting situation. Now you haven't made that connection but I just wanted to make that point. Retrofitting costs can be several times the equivalent cost for a new plant.

Q. If we are talking about filtration for a moment, or filtration combined with ion exchange, we looked a moment ago at page 82, and you told us that some of the plants have those systems but they are not used where it's not necessary to reduce the emissions

because the emissions are already below 1 per cent of derived emission limits; right?

A. Yes.

Q. And to the same point as the statement on page 83 that there is at present no strong reason for increased operation of these filtration and ion exchange effluent control systems if what you are looking at is the percentage of derived emission limits and being below 1 per cent?

A. That's true.

Q. But it would seem that you could spend between $1,500 and $6,000 a year in 1987 dollars and, according to this report, reduce annual emissions, total liquid emissions, by a fairly significant number. They reported here from 70 to 38 and we know we have a problem with those numbers.

But would you agree that there could be significant reductions in total liquid emissions completely apart from the issue of the 1 per cent of derived emission limits by the use of filtration?

A. Well, I'm not at all sure how that $3,000 estimate was derived, what that assumes in terms of utilization, so I really can't comment. I guess the table that sort of puts it all together is table 2.

Q. So it shows us that with filtration

you would reduce the effluent by 56 per cent with a total collective dose reduction per person sievert of 3 -- of person sieverts, sorry, and a cost of .15 million dollars in 1987 dollars over 50 years?

A. Well, that's what it says. But really without knowing the details of how they come up with that cost, it's difficult for me to say whether that would be in addition to what we are already doing and therefore whether indeed by doing what is suggested here we would effect any reduction.

Q. Right. Although we saw a moment ago at page 82 and 83 that their statement of current liquid effluent practices is consistent with what you say you are doing right now; is that correct?

A. Yes.

Q. I would like to refer you to page 104 of this exhibit while we are speaking about this. This is an excerpt from Ontario Hydro's State of the Environment Report in 1989.

A. Yes.

Q. And under the topic "Issues" about two-thirds down the page, there is a statement that AECB has indicated that filtration of all liquid effluence to remove radioactivity and particulates prior to release to the environment is general practice

worldwide. Presently Ontario Hydro filters as required to be below 1 per cent of the regulatory emission limit.

So, in other words, it would seem that Ontario Hydro's practice is not consistent with the filtration practice which is commonly practiced throughout the rest of the world; is that what it's saying.

A. Well, it may well be with other reactor systems that there is a need to filter continuously in order to maintain emission levels below the appropriate levels in those jurisdictions.

The fact is that we don't need to in order to maintain our emissions well below the operating targets. That's not to say that we are not thinking about making certain improvements where it makes sense to do so. I guess under the initiatives column opposite the paragraph which you referred to, there is an indication of just that: that you are testing other possibly less costly methods of treatment such as reverse osmosis?

A. Yes, less costly methods. I am not sure that I would agree that reverse osmosis is a less costly method or even an effective method on a commercial scale. I happen to doubt that. But I think

the general intent of that statement I would agree with.

I think I referred to the Bruce "A" rehabilitation program a little while ago. And that second paragraph or second bullet indicates that there is quite an effort under way to examine the different sources of liquid waste at the Bruce "A" station and ways of reducing emissions to the environment.

So I guess what I am saying is that it is not a static situation at all and it's a question of finding mitigative measures that are effective and cost-effective.

Q. But it would appear from this that you have got in fact already in place and some of the stations filtration or ion exchange systems which you are just not using because you say you don't have to worry about it, you are already below 1 per cent of the DEL; right? And it seems to me that it would be a fairly straightforward matter to use those systems that are in place, and it would appear from this report that you could achieve pretty significant reductions of liquid emissions by doing that at relatively little cost.

MR. B. CAMPBELL: Excuse me, Mr. Chairman. Hasn't this witness indicated that it is not

clear from the report that that is the case. The report refers to reference from units of 70 down, and I think Mr. Johansen has indicated that he is not at all sure that that would be the case at the levels that are currently occurring at Ontario Hydro's stations. I think that's the evidence.

[3:25 p.m.]

MS. McCLENAGHAN: Q. At page 89 of this document, Mr. Johansen, there is a table, table 21, titled Global Collective Dose Commitment from Darlington.

THE CHAIRMAN: This is part of the Atlantic Report, is it?

MS. McCLENAGHAN: Yes.

MR. JOHANSEN: Yes.

MS. McCLENAGHAN: Q. And it shows a figure for carbon-14 that there could be an 89 per cent reduction with technology for carbon-14, in the emissions of carbon-14.

MR. JOHANSEN: A. Well, that's certainly what it shows, but I am not in a position to support that figure.

I have some doubts about that based on a preliminary analysis that I am aware of that have been carried out in Ontario Hydro. And I guess I would go

back to what I said earlier about the uncertainty in the estimates of collective dose, as pointed out by the authors themselves on the summary page, which would have been the page following this one in the full report.

Q. The technology that they are referring to, I think is referred to on page 87 of the exhibit, being calcium hydroxide scrubbers?

A. Yes, I see that.

Q. And is that what you are familiar with when you are making the comment you just made?

A. No.

Q. Are you familiar with calcium hydroxide scrubbers as a technical means of reducing carbon-14 emissions?

A. In general. I have not seen an assessment, a technical assessment of calcium hydroxide scrubbers for carbon-14.

MS. McCLENAGHAN: I think, Mr. Chairman, this would be an appropriate place for a break because I will be switching gears.

THE CHAIRMAN: All right. We will break for 15 minutes.

THE REGISTRAR: Please come to order. The hearing will recess for 15 minutes.

---Recess at 3:30 p.m.

---On resuming at 3:45 p.m.

THE REGISTRAR: Please come to order. This hearing is again in session. Please be seated.

THE CHAIRMAN: I have been told that the premises across the road are now devoid of electrical power. What inference to be drawn from that I don't know, but one consequence is that the transcripts which are normally available first thing in the morning may not be available first thing tomorrow morning because that's the head office of the reporting group. So they will be ready as soon as possible, but no sooner.

Ms. McClenaghan?

MS. McCLENAGHAN: Thank you.

Mr. Chairman, it's my intention to deal with some questions arising from the package we submitted as Exhibit 598, Materials on Inherent Hazard of CANDU Reactors, and I will be returning in the morning to a few questions with regard to toxicity and those materials.

Mr. Tom Adams is sitting beside me at this point from Energy Probe.

Q. And my questions, I assume it might be Mr. King who is answering these questions related to the need for safety systems at CANDU stations; is that

fair.

MR. KING: A. Yes.

Q. Now, Mr. King, obviously it almost goes without saying that the reason you need safety systems is connected to the topics we were discussing earlier today, i.e., the toxicity radioactivity of the fuel that the CANDU system uses; is that fair?

A. They are associated with keeping radioactivity separated from the public, yes.

Q. And would you agree that it is, of course, the fuel itself that produces what we might call the hazardous conditions that exist in a CANDU reactor like the heat, the pressure, the neutron flux and the toxicity?

A. Well, the hazardous conditions, you have to define -- like pressure and temperature, it depends on what is nearby to make them hazardous. Most of the radioactivity comes from the fuel, not all, but most.

Q. All right. And it is the fuel itself as well that produces the heat that exists while the reactor is operating; right?

A. The majority of it, yes.

Q. And it's the heat and temperature that results in high pressure conditions in the

pressure tubes and the heat transport system; is that right?

A. Yes.

Q. Now, I think you testified earlier that once the fuel is -- that there is no way to stop production of the heat from the fuel except the passage of time. In other words, you can't just shut down the reactor and it stops producing heat that minute. It keeps producing heat.

A. There is decay heat, what is called decay heat, which after you shut down the reactor it continues and then it lowers with time, decreases with time.

Q. All right. So that's very different from a situation with, for example, a kettle which you unplug it and it stops producing heat; is that right?

A. I guess that's a reasonable analogy.

Q. Now, I understand that a reactor operating at full power, a nuclear reactor is producing 1,800 megawatts of thermal heat; is that right?

A. It depends on what size the reactor is.

Q. The Pickering sized reactor, for example.

A. Well, the Pickering reactor produces

around 540 megawatts electrical. Assuming that the efficiency of the conversion, electrical conversion process is around 30 per cent I believe, it would be 540 divided by .3, which would be around 1,800 megawatts thermal.

Q. All right. And the minute the reactor is shut down or the minute after it's shut down, the reactor continues to produce, I understand, 7 per cent of that power?

A. No. Well, perhaps the instant it is shut down, but it decays very rapidly in the first few seconds. So at the end of a couple of minutes, I believe it's down around 3 per cent, but these are approximate numbers. I would have to check to get the exact number.

Q. Now, as I understand it, whether the reactor is running or not, what is taking the heat away is the coolant; is that right?

A. Heat appears in the moderator and the heat transport system, but the majority of the heat is being removed by the heat transport system, the coolant, yes.

Q. Am I right that the coolant inside the pipes is over 1,400 pounds per square inch pressure?

A. At normal operating conditions it would probably -- it varies within the circuit, but I would think in the 1,500 PSI, pounds per square inch, is a good number to refer to.

Q. And to put it in perspective, do you know what the pressure inside a common household pressure cooker would be? Would about 15 pounds per square inch sound right?

A. I have no idea.

Q. Would you agree that the coolant would react much like the water inside of a pressure cooker if there was a breach of the pipe? For example, the coolant would rapidly turn to steam and escape?

A. Well, the coolant is primarily in a liquid form when it's in the heat transport system. If you have a rupture in it, then through the latent heat of vapourization, some of it will turn to steam. I think the ratio is something like one-third to two-thirds, one-third will come out as steam, two-thirds will come out as water.

Q. Am I right in understanding then that the reason you need this safety seem called emergency core cooling would be to replace that coolant in that sort of an eventuality?

A. It's used to maintain the fuel in a

condition such that there is no damage to the fuel, yes, by removing heat from the fuel.

Q. I want to refer you to page 59 of the exhibit package, 598, which is Interrogatory No. 9.2.71.

THE REGISTRAR: The 9.2.71 is .95.

---EXHIBIT NO. 520.95: Interrogatory No. 9.2.71.

THE CHAIRMAN: Just bear with us for a minute, we are just getting organized here.

What page?

MS. McCLENAGHAN: It's the very back page of that exhibit package.

Q. That interrogatory, Mr. King, that interrogatory response is dealing with the emergency coolant injection system at Bruce "A" and at Pickering "A". And, firstly, under paragraph A, you state that:

> The AECB requested Ontario Hydro to consider how the undesirable situation of a common device serving a process system, moderator level control and a safety system, emergency coolant injection system should be rectified in order to follow the principle of separation between process and safety systems.

First of all, can you explain further

what a process system is as opposed to a safety system?

MR. KING: A. Well, a process system is used in the -- it's a normally running system, used in the power production process, whereas a special safety system is a system, is the containment, ECI, or shutdown system No. 1 or shutdown system No. 2.

Q. And why is it undesirable to have a common device serving both?

A. The situation why you try to make them separate is that you don't want to have a device that could fail and cause a process system failure and that same device be used in a safety system which would be used to mitigate the consequences of that process system failure. That's the intent behind the rule.

Q. And was that the situation at Bruce "A"?

A. Well, the situation that they were referring to in this point (A) on this page, refers to, as it says there, moderator level control. The end element of the moderator level control or moderator level measuring system, there are some small what are called impulse lines coming from the top part of the moderator and the lower part of the moderator, going through a device called a pot, p-o-t, common jargon, and that, those parts of the moderator level measuring

system were used to derive a signal for the moderator level control. As well in this particular reactor, Bruce "A", a signal was derived with some other instrumentation, separate instrumentation, but there was a sharing of instrumentation up to that point, which would be used to initiate the emergency coolant injection system, or some aspect of the emergency cooling injection system.

Now, the current status of this situation, of course, these points are referring to correspondence or issues which have been or are being discussed with the Control Board, is that the solution that we are looking at is to redo the analysis and see if we can come up with another ECI initiation parameter, different from the moderator level.

But, the issue, while it breaks the spirit or the letter of the law on the separation requirements, it's not considered a major point because of the kind of lack of causal relationship between failures in the moderator level control system, and the ECI system. There are no failures in moderator level control which could result in the need for the ECI system. So that's why is not been given -- it's not a major issue between us and the AECB at this time.

Q. Are you saying that it is not a major

issue today?

A. That's correct.

Q. But am I to understand that it was a major issue with the AECB earlier?

A. No, I think it's always been the same.

If the situation were kind of the letter of the rule, the separation of the two process systems and safety systems has not been met in this case, but from an increased risk point of view, it's not felt to be an important matter. But in the longer term we would hope to follow the letter of the rule as well, and the solution that we are looking at when we redo this analysis, and this analysis is scheduled for in the near future, I believe, is that we will look for another initiation parameter for ECI.

Q. Was it the case that Bruce "A" did not comply with, as you put it, the letter of the law, at the time when it was licenced in this respect?

MR. B. CAMPBELL: Just a minute. The language is starting to, Mr. Chairman, get just a little loose here. We have had this referred to once as the letter of the law, once as --

MR. KING: I think I used the term letter of the rule.

MR. B. CAMPBELL: I think the transcript will show you have use it had both ways, and I like to be clear which one we are talking about here, because my friend is starting to repeat the language.

MR. KING: I meant to say the letter of the rule, to distinguish it from any legal context.

MS. McCLENAGHAN: Q. Was it a licensing requirement that there be separation between the process and safety systems at the time when Bruce "A" was licenced?

[4:03 p.m.]

MR. KING: A. That is one of the rules in the siting guide that would have applied to Bruce "A".

Q. And as I understand it, Bruce "A" was licenced and allowed to operate even that was an outstanding issue?

A. I am not sure when it was recognized to be an issue.

Q. I understand from your comments a few moments ago --

A. In fact, okay. It would be my guess that it was probably not an issue at the time it was licenced. We have probably put in that new trip parameter on ECI since it was originally licenced -- an

initiation parameter on ECI, should have said, on moderator high level. That probably would not have been in there on the original mid-70s design when it was licenced.

Q. This emergency cooling injection system that you are describing is not the same as the high pressure emergency coolant injection system?

A. Yes, it is.

Q. It is the same; that's what you are talking about?

A. Yes.

Q. Is it the same problem or was it the same problem that exists at Pickering "A"?

A. Are you referring to what is in the bottom paragraph on this page right now?

Q. Yes.

A. No, what is written in the bottom of the page doesn't relate at all to the Bruce "A", paragraph A situation.

Q. Can you describe what the concern was or is at Bruce "A" regarding the high pressure emergency coolant injection modifications? Why were they needed?

A. I think I mentioned in my evidence in chief that the Bruce "A" and Bruce "B" and Pickering

"A", the ECI systems were upgraded. Essentially what has happened at Bruce "A" and Pickering "A", is we have increased the pressure available for the initial injection phase, and that's what it is referring to in that first sentence:

"Ontario Hydro completed the installation and commissioning on all four units of the high pressure emergency coolant injection modifications."

If you continue in that paragraph -- well, the next sentence just refers to some correspondence. The more substantive of these relate to the steady state thermal hydraulic analysis. I'm not exactly sure what's being referred to there.

The water hammer analysis, whenever you inject high pressure liquid into, especially into a piece of piping which may be void, there is always a potential for water hammer. And I believe the correspondence was referring to possibilities for being in that situation.

There is valving which separates the light water high pressure emergency coolant injection system from the heat transport system. There are two sets of valves and it does have an interspace which we normally keep full of water. In fact, one of the

design modifications referred to in the very last sentence there of the Pickering "A" discussion, one of the minor modifications referred to in that last sentence was to do with an increased, a larger valve that we put in for draining an interspace between some valving in that line.

Continuing on with that sentence, starting "The more substantive...." the last point being the environmental qualification, the ECI system when the high pressure was backfit and improvements were made to the remaining part of the ECI system, which weren't directly associated what the high pressure supply, water supply, there were environmental qualification improvements made and there was a documentation, reports sent to the Board which supported the fact that the ECI system was, based on these modifications, considered to be environmentally qualified.

Q. When was it that the AECB originally indicated that this modification was needed?

A. The...?

Q. The high pressure retrofit.

A. I would just be going from memory. I would think it would be in the '80 to '82 sort of period, but I could be off a couple of years.

Q. And what about at Bruce?

A. I think the issues arose about the same time, '80, '82.

Q. And they were completed when?

A. In Bruce, I don't have that date. I guess on the Pickering I assume some of the modifications went in when we did the retubing and maybe Mr. Daly can help me there.

MR. DALY: A. I think on Bruce my recollection would be that it finished around '85, '86. And Mr. King is right. Some of the these ECI modifications were done during retubing which started in '83 and continues, but I believe the last unit was done in an earlier outage. So I think sort of the period between '84 to about '89 is my recollection.

Q. Mr. King, you testified earlier in the hearing that you have two independent shut-down systems at all of the stations except Pickering "A"?

MR. KING: A. Yes.

Q. Which I understand is the case.

Why is it so important to have a reliable and effective shut-down system?

A. Well, if you need to shut down the reactor quickly, there are other systems, the regulating system, which you can shut down the reactor

under normal situations, but there are situations which can arise caused by process system failures which create the need to shut down quickly and that's why you need the shut-down system.

Q. Can you give some examples of some process estimate failures that would result in the need to shut down quickly.

A. There is the whole range of loss of coolant accidents. The very small ones can be within the -- we have a rule that we use in safety analysis that you can't take credit for operator action within the first 15 minutes. For the smallest of the lost coolant accidents you don't need to take that action for later than 15 minutes, so we can credit manual shut-down.

For the larger loss of coolant accidents, you need to shut down within the 15-minute period and you are relying on the automatic shut-down of the action of the shut-down systems.

There are loss of regulation accidents, loss of feed water, steam line failures. There is a whole range of accidents, and I believe in my direct evidence when I was talking about the deterministic safety analysis I probably listed 10 or 12 classes of accidents which are analyzed in the safety report.

Q. You also testified earlier at Volume 123, page 21504, that a second advantage of CANDU generators was that they have two shut-down systems. Do you recall that?

A. Well, there is no doubt that, as we have already discussed, all reactors with the exception of Pickering "A" have two fully independent capable shut-down systems.

Q. Now in terms of characterizing that as an advantage of CANDU relative to, I think you were talking about the PWR or the BWR --

A. Well perhaps if we are going to stay with the transcript I should get the exact line.

Q. Page 21503, at the bottom you speak about the advantage of the CANDU, over to the top of 21504. And then at line 22 you said the second advantage --

MR. B. CAMPBELL: Mr. Chairman, the comment from the 21503 on to 21504 is actually the question.

MS. McCLENAGHAN: Yes, I stand corrected, I'm sorry.

MR. B. CAMPBELL: Mr. Heintzman would be pleased to give evidence on this topic I have no doubt but...

MS. McCLENAGHAN: Q. The question at the bottom of 21504 is asking: Is the second advantage of the CANDU the fact that units other than Pickering have a dual shut-down mechanism? Would you consider that to be an advantage? And at page 21505 you said. Yes.

MR. KING: A. Okay, I see that.

Q. I just wanted to clarify that you can only consider a second shut-down system to be an advantage in a situation where you need a shut-down system in the first place because your technology is so hazardous; isn't that fair?

A. I believe I have discussion with Mr. Heintzman - I am not sure whether it's spread on these pages - about the characteristics of a particular type of reactor; that some types of reactors have these characteristics and some other reactors have different characteristics and generally you design your safety systems in relation to those characteristics.

In the situation with our reactors, now we have got some systems which are different than light water reactors, and one of the explanations is that the demands of the various types of reactors are different.

Q. So would it be fair to say that it's not necessarily an advantage; it's just a difference?

A. Having two is better than one.

Q. Having two in a CANDU is better than one?

A. No, other reactors, the Sizewell B reactor in the U.K, which is a basically a Westinghouse-type LWR, it has two shut-down systems. There are other future reactors being designed which are non-CANDU, which have two shut-down systems as well.

Q. So you are saying that it's an advantage to have two shut-down systems for nuclear generating technology?

A. Well, two is better than one; three is better than two. There is a law of diminishing returns. I wasn't be being asked here to quantify the extent of the advantage.

Q. I think you testified earlier that positive void coefficient of reactivity means that if your reactor loses coolant, the fuel continues to produce heat and in fact it heats up. Is that fair, a fair description?

A. It's better than Mr. Hamer's, but... [Laughter] I won't go into the long explanation again.

When the void increases, the nuclear reaction increases and that heats up the fuel more.

Q. Is it fair to say that only two types

of large nuclear power reactors in common use in the world which have a positive void coefficient of reactivity are the CANDU and the RBMK or Chernobyl design?

A. Both of those reactors have positive void coefficients, yes.

Q. And there aren't any others commonly used, large nuclear power reactors, which have positive void --

A. I don't believe so.

Q. And isn't it also true that the only two types of large nuclear power reactors in common use in the world which use pressure tubes are the CANDU and the RBMK or Chernobyl design.

A. Well certainly they both do. I am aware of other power reactors which have pressure tubes but if you are saying in wide use, then no, there wouldn't be other ones in wide use.

Q. Right. And would you agree that the positive void coefficient of reactivity was a design feature that rendered the Chernobyl reactor vulnerable to the disaster it had?

A. Well, there were several design features which I have covered in previous discussions with Mr. Heintzman on this point or Mr. Hamer. One,

the lack of a fast shut-down system at Chernobyl was a very important factor in the progression of the accident.

Q. And the reason for that was because of a positive void coefficient of reactivity in that reactor; is that right?

A. That's not why they didn't have a fast --

Q. No, but that's why they needed one?

A. Yes, that's correct.

Q. So without that fast shut-down system, that's a characteristic of that reactor that rendered it vulnerable to the disaster that happened there.

A. There was a large number of factors. The existence of a positive void co-efficient; the lack of clear procedures and having people follow those procedures; the lack of a fast shut-down system. They were all contributing factors.

Q. So, it would be fair to say that in order to avoid that kind of disaster you need the very fast shut-down system, the well-trained operators, and numerous other safety systems in place that all work when they are supposed to?

A. There are all sorts of factors you

need to have in place. Right now we are just discussing a certain type of accident at the RMBK-type of reactor. If you want to characterize what has happened at Chernobyl as a large release, then there are other mechanisms in other various types of reactors which can have large releases and which have design features which are beyond the ones that we have just talked about to prevent those large releases from occurring.

Q. Do you know what prompt super criticality means?

A. Yes.

Q. Would you be able to describe it to us?

A. It is when you have one of the features of the fission process which allows nuclear power to exist as a vehicle for producing electricity in power plants. It's the fact that not all the neutrons which are created in the fission process come out as fast neutrons as soon as the fission of the uranium occurs. Some of them come out a little later, going from fractions of a second to several seconds.

And these delayed neutrons are the ones that in fact allow the reactor to be controlled. And what you need to have a self-sustaining fission

reaction is a net of one neutron per generation.

If you have a fission occurring and then you want to maintain a self-sustaining fission, a chain reaction, then you have to have so many generated typically in the order of 2 neutrons per fission. Some of those get absorbed in the materials inside the core. And if you have a net of one that's available for creating another fission, then you have got a chain reaction.

If that's the delayed neutron which allows that to happen, then you can have a -- or if that's the important part which allows that to happen, you can have a controlled reaction. But if you have an excess of neutrons, fast neutrons, then you can get into the a situation called prompt criticality.

[4:25 p.m.]

You are becoming critical on your prompt neutrons, not your delayed neutrons.

Q. What is the rate at which the power increases if a reactor goes prompt super critical?

A. I don't think I could express that rate.

Q. Would it be fair to say it's something like between tenfold and a hundredfold per second?

A. I would have to dig out... Are you talking any reactor, are you talking about --

Q. The CANDU reactor.

A. Well, there are materials in one of the exhibits we have filed which is the loss of shutdown at Pickering analysis which was done for the Hare Commission, which would have that number in it. I would have to refer to that to give you a rate.

Q. And is it fair to say that if a reactor is prompt super critical or the power is increasing at a fast rate or an extremely fast rate, that in effect you have lost control of the reaction?

A. If it's prompt super critical then there is no doubt you have lost control of the action.

Q. And it is my understanding that the Chernobyl reactor went into a state where it was prompt super critical prior to the accident which occurred there; is that right?

A. Yes. But there are differences between the design of the Chernobyl reactor and a CANDU, and if you go to that --

THE CHAIRMAN: But she didn't ask that question. She may ask it later, but right now she hasn't asked that question.

MS. McCLENAGHAN: Q. So the answer is

yes; is that right?

MR. KING: A. Could you repeat the question?

Q. The Chernobyl reactor prior to the accident that happened there was in a state of prompt super criticality?

A. Yes. It was not prior to the accident, it was during the accident.

Q. Happening pretty fast.

Are you familiar with the phrase pipe whip restraints?

A. Yes.

THE CHAIRMAN: Sorry, I didn't hear that.

MS. McCLENAGHAN: Pipe whip restraints.

Q. Could you explain what that means?

MR. KING: A. If it is assumed that when a pipe fails, it fails in a guillotine manner, that is normally when pipes fail they don't fail in a guillotine manner. You will get a crack, it opens up and what is typically referred to as a longitudinal or fish mouth type of rupture. But if you assume that the pipe just breaks right through completely, that's referred to as guillotine-type rupture.

With a guillotine-type rupture, and we were talking earlier about the discharging high

pressure steam and water, because of the reaction forces to that, if that water is coming out of one end of the pipe there is a reaction force causing that pipe to whip. If you cannot stand the consequences of that pipe whipping and hitting something else, and one of the design vehicles for preventing that consequence or that impact of the pipe with some else, is that you design a restraint. It's effectively a collar on a piece of pipe which is held back to an anchor in the concrete wall typically.

Q. And I understand that the restraint is both a benefit and a disadvantage. A benefit in that it would present this occurrence that you just described presumably, and a disadvantage in that it is a barrier to inspecting the pipe in the first place?

A. It depends on where the restraints are fitted. Typically, you do inspections of pipes at high stress points or at welds. So if you can avoid those locations in setting your restraints, then it's not a disadvantage for that reason.

Q. Do you find that it often is a disadvantage?

A. I couldn't say with respect to the inspection reason. But there certainly is in general terms, as you say, advantages and disadvantages, and I

think you have to look at almost each restraint to make a decision on what conclusions you should draw from that balance.

Q. Mr. King, before I go too far away from the question I was asking you a moment ago, I don't know whether I asked you the question, I think I thought I did, whether there were any circumstances when a CANDU reactor could be prompt super critical?

A. Well, yes, and that reference I gave you to the Pickering loss of shutdown analysis discusses that.

Q. Would you be able to tell me what a flux tilt or a flux oscillation is?

A. Yes. With a large core there can be a situation where you have one part of the core has a higher neutron flux than another part of the core, and it is oscillating in an oscillation mode.

Normally within a core -- and the absolute flux is different in every place in the core, there is a shape, in the centre it's higher than at the edges, but you can get into a situation where either axial or longitudinally that the flux moves back and forth. And the cause of it is the creation and burn off of xenon which is a result of the fission process but is an absorber of neutrons.

There are spacial flux control mechanisms in the reactor to control flux, not from an overall point of view but from a spacial point of view. The liquid control zone is of system is what I am referring to.

Q. When you have a situation as you were just describing when you have a flux oscillation, is that a situation in which you have an unstable flux tilt? Would that be a fair description or could that be unstable?

A. If you mean unstable in that it is getting larger rather than getting smaller, is that what you mean?

Q. Yes.

A. Yes, that could occur.

Q. I want to refer you to page 39 of the exhibit package.

THE CHAIRMAN: 598?

MS. McCLENAGHAN: Yes. Page 39 of Exhibit 598.

Q. And that's a document dated February 1991, titled, A Follow-Up Report, Unit 2, Severe Flux Tilt Resulting in Forced Outage.

MR. KING: A. Yes.

Q. It's referring to an incident I

understand that happened September 27, 1990?

A. Yes.

MS. McCLENAGHAN: Perhaps that should be given the next exhibit number, Mr. Chairman.

THE CHAIRMAN: Thank you.

THE REGISTRAR: 602.

---EXHIBIT NO. 602: Document entitled: A Follow-Up Report, Unit 2, Severe Flux Tilt Resulting in Forced Outage, dated February 1991.

MS. McCLENAGHAN: Q. Now, first of all, on page 40 of the exhibit, the introduction states that an incident occurred in September 1990 when the insertion of an adjuster rod into the Unit 2 core lead to a severe side to side flux oscillation, which continued for two cycles until the unit was shutdown on September 27th, 1990; is that right?

A. That's what happened.

Q. So it continued for two days until the unit was shut down?

A. Yes.

Q. And on page 43 of this exhibit, under the title Basic CANDU Reactor Physics, there is a discussion that finishes with the sentence:

Like the positive void coefficient, the potential for flux oscillations is a

fundamental albeit undesirable characteristic of CANDU reactors which must be addressed both in the design phase and during operation.

Can you describe what it is that's undesirable about that characteristic, i.e., the potential for flux oscillations?

A. Well, the power in the reactor, in our reactors is limited from an overall reactor point of view, as well as on a channel basis, there is a maximum channel power, as well as on a bundle power, each of the bundles that Mr. Daly had, there is a limit on the power you can get out of the -- the maximum power you can get out of a bundle.

When you get into a flux oscillation situation, the reason you want to avoid it is not to exceed either a channel or a bundle power limit. You can get into a situation where the total core power isn't exceeding the rated level, but perhaps a channel power or bundle power would be.

So what you do is you design your whole scheme of measuring the flux in the reactor, and your protection for the bundles and the channels through the automatic shutdown of the reactor to prevent these limits from being exceeded.

Q. Now, I understand that, and maybe you can tell me if this is right, that a situation where you have an unstable flux oscillation occurring can lead to a situation of prompt super criticality; is that right?

A. I don't believe so.

Q. If you had a loss of coolant accident at the same time?

A. Well, it would be the loss of coolant -- you are talking about a loss of coolant accident and if the -- you would not get prompt criticality with the loss of coolant, if that's your scenario. If you have a flux oscillation and a loss of coolant accident, those are the two things that have happened, you cannot get prompt criticality.

Q. What would happen if you had the unstable flux oscillation occurring and your shutdown system didn't work when you had your loss of coolant accident?

A. Well, we have a loss of coolant, flux oscillation, and your shutdown systems have failed, that's the -- well, the latter two of that sequence is what is analyzed for Pickering in the Pickering loss of coolant -- loss of shutdown analysis which was done for the Hare Commission. There was a large report done on

that which was also -- and critical parts that have would done independently by the Argon Laboratories in the states as well.

Q. So, in other words, in that analysis I think you told me a few minutes ago, that you could have the situation where the reactor does achieve prompt super criticality?

A. That's what is documented in the report. But we are talking about very, very low probability, non-design basis accidents here.

I would like to refer to you page 36 of this exhibit, and this is I understand from Exhibit 104.

THE CHAIRMAN: 104?

MS. McCLENAGHAN: Rather from Interrogatory 9.2.104.

THE REGISTRAR: Which is .96.

THE CHAIRMAN: Thank you.

---EXHIBIT NO. 520.96: Interrogatory No. 9.2.104.

MS. McCLENAGHAN: Q. That's a report of the Ontario Hydro Nuclear Integrity Review Committee, dated August 1991?

MR. KING: A. It's an excerpt from the report.

Q. Yes. And the excerpt that's

contained here at page 37 and 38 of Exhibit 598 describes the Pickering "A" Undamped Side-to-Side Neutron Flux Oscillations, which is the incident that we were talking a few minutes ago which occurred in September 1990; is that right?

A. It's referring to the same incident, yes.

Q. And at page 38 of the exhibit there is reference to the main causes of the event, and paragraph B refers:

> To insufficient station emphasis on the importance of conservative decision-making.

And I my question is whether you know what that refers to, what does that mean?

A. Yes. It refers to the situation where the reactor operators, and this occurred over, as you pointed out, a couple of days, that the reactor operators did not view it as important enough to shut down the reactor, given that they didn't fully understand what was occurring.

There were no limits being exceeded, through this whole incident no fuel failed at all. But they were in a situation where they were trying to recover from these oscillations, they have had similar

oscillations in previous months where they did recover from it.

Having flux tilts was not unexpected and they had a certain procedures in dealing with them. This just happened to be a little more severe than their previous experience.

And really, the importance that Ontario Hydro has placed on this event and the importance that the AECB has placed on this event is related to, is what you pointed out here, is the lack of conservative decision-making. That's what the I think the AECB was mainly concerned about.

Subsequent to this event, in January of the following year, 1991, the Mr. Horton, Elgin Horton who is the vice-president of nuclear operations branch, sent a letter to all the shift people, all the authorized first operators, shift supervisors, explaining his view on the subject, and that they should be taking -- their decisions should be conservative, that there is no penalty at all involved with taking conservative decisions and shutting the plant if they don't understand what is going on. And I believe the AECB and some of the subsequent annual reports for Pickering and Bruce have noted the fact that they have noticed, from their talking with shift

personnel, that the message has gotten through, and I think the mood of conservative decision-making has been reinforced from the top and it is really a way of life now on the shifts.

Q. If you look at page 54 of this exhibit package which refers to interrogatory to No. 9.2.70.

THE REGISTRAR: .97.

THE CHAIRMAN: Thank you.

---EXHIBIT NO. 520.97: Interrogatory No. 9.2.70.

[4:44 p.m]

MS. McCLENAGHAN: Q. I understand that there were two flux tilt events on another occasion, according to this, at Bruce "B" in 1988; is that right?

MR. KING: A. Yes, this was a couple of years before the Pickering incident.

Q. And it states in this interrogatory response in this second paragraph under Bruce "B" that Ontario Hydro prepared more explicit instructions on the handling of severe flux tilts. Ontario Hydro reviewed training and concluded that improvement was needed in several areas related to reactivity device abnormalities and committed to address the training deficiencies. And I gather that happened, did it?

A. Yes, it did.

Q. And it was after that that you had the September 1990 accident that we have just talked about where there was, as it was put in that document, a lack of emphasis on conservative decision-making. And so it would seem that the earlier training and instructions were not adequate to prevent the subsequent event; is that fair?

A. One of the issues that came out in the evaluation of the second event, the Pickering event, was the fact that two similar events had occurred in Bruce and they had put in some better procedures for handling such incidents at Bruce, but that the messages did not get fully communicated from one station to another station. What we are talking about here now is Bruce.

Q. Yes

A. And I think that was also found in some of the, I believe that follow-up report that we were discussing earlier, I believe there is some reference in there to the Bruce events and the fact that the lessons learned at Bruce or the procedures, the improved procedures that were instituted at Bruce did not get communicated effectively enough to the staff at Pickering.

Q. I understand that a part of the cause

of this sort of accident or these events was ironically a safety upgrade that Ontario Hydro had made; is that right?

A. We are talking of Pickering right now?

Q. At Pickering, yes.

A. Yes. When we increased -- the answer is yes.

Q. And could you describe what that safety upgrade was?

A. In the original Pickering "A" design there was a 11 shut-off rods; that has subsequently been increased to 21 shut-off rods. These are rods which are being dropped in from above. To gain those additional ten sites in the core, we had to remove 10 adjusters.

Now in the original design there were 18 adjusters. Adjusters are neutron-absorbing materials. At Pickering they are primarily cobalt. In fact, this is the source of the cobalt which Hydro produces and is used in the medical, the cancer machines around the world.

But these adjusters have a certain worth; they have a certain capability to absorb neutrons. And when we went from 18 down to 8, because we took 10 of

the sites, the places in the core, to change those into shut-off rods, we had to make the worths of all the adjuster rods the same. Before we had a maximum worth and then we had other rods which had lesser worth. Well, now we made them all the same, so there are 8 rods of high worth. That means that they have a high capability to absorb neutrons.

Now in this particular incident at Pickering "A", there had been some loss of reactivity due to lack of ability of fueling machines to refuel the core. One of the purposes of the adjuster rods is that if you are in these situations, the adjuster rods which are normally in the core at all time, you can pull some of them out, increase your reactivity if you have a lack of fueling capability due to fueling machine problems.

Pickering "A", just prior to this September 1990 incident, had the adjuster rods out of the core and the operator was going towards the more normal situation of having adjusters in the core and inserted an adjuster rod, and that was kind of the initiating event for the flux tilt. So, it's related to the fact that the worths of the adjusters rods are higher because of the fact that we took 10 of the sites and made them shut off rods.

Q. And the adjuster rods when you say have the ability or capability to absorb neutrons, that's a component of controlling the rate of reaction; isn't that....

A. No they are used to shape the flux. They are normally in the core and they are normally towards the centre of the core. So, rather than having a very peaked flux in the centre, you can kind of cut off the top of the peak. It allows you to raise the power more evenly throughout the whole reactor by cutting off the peak.

Q. So as a result of the changes of some of the adjuster rods to shut-down rods, did that result or does that mean Pickering is now more prone to flux tilt problems than it otherwise was?

A. Prior to this incident. Subsequently, the offending rod and it had a -- normally what you do is you insert two rods, symmetrical rods. If you have to insert a rod, you simply insert two on each side and therefore you don't get the tilt situation.

In this particular situation, the operator only inserted one on one side. And the normal action is to then refuel a channel near that rod because by inserting the rod, you are putting in

negative reactivity. The normal operator action is then to refuel the channel near the rod to put in positive reactivity and hence you even things out and you don't get the flux tilt.

What happened in this particular incident is there wasn't a channel which met the criteria close enough to the adjuster rods that the operator needed to refuel and he went slightly outside the established criteria and refueled another channel, which didn't have the same balancing effect.

Q. I would like to refer you next to an excerpt from what is Exhibit 187 and is contained at page 14 of the exhibit package that is before you; that being the Ontario Hydro Submission to the Ontario Nuclear Safety Review of August 1987.

And the excerpt contained under the topic "Inherently Safer Reactors" is at page 16 of the exhibit package. And it says in the third paragraph on page 16, that:

"'Inherently safer reactors' are being designed to be able to shut themselves down and continuously cool their cores in the event of an accident, without having to rely on external power, mechanical devices or human operators for an

extended period of time. "

And I take it that the CANDU of course is not inherently safe in any of those ways?

A. The whole term "inherently safe reactors" -- as you note here it's in quotation marks, and that's for a specific purpose. The term "inherently safe reactor" arose in the mid-1980s, I believe. Right now it's not a term that is in general use. I know the International Atomic Energy Agency in their definition of terms for future reactors do not use the term at all.

[4:55 p.m.]

But we were asked here, this is Ontario Hydro's submission to the ONSR, we were asked, as well as AECL was asked, to submit materials related to this subject, in Dr. Hare's words, inherently safe reactors. We chose to change the terminology a wee bit to safer and then put it all in quotation marks.

These few lines that you just read out are referring to "inherently safer reactors", and I believe the discussion goes on, later on to some reactors which are power reactors and some reactors which are not power reactors. There are some of them which are just district heat, water heating type reactors. And the design, the state of design of some

of these reactors is very, very early on, very early conceptual design, and none of these reactors are -- some of these concepts on the following pages here are dead concepts, nothing is being proceeded on them.

But some of them do, some of these concepts these people have come up with do have a concept which allows for them to be shut down with passive means. And I much prefer the term passive rather than inherently.

Q. All right. And if you use the term passive, I might refer you to page 27 of this exhibit package, which is AECL's submission to the Ontario Nuclear Safety Review of August 1987, and it contains an excerpt from appendix 2, under the topic Inherently Safe reactors. Towards the end of that page there is a paragraph that says: In common terminology -- beginning in the second sentence --

A. Sorry, I haven't got this.

Q. The last full paragraph on the page.

THE CHAIRMAN: We better give this one a number.

THE REGISTRAR: 603.

---EXHIBIT NO. 603: Document entitled: Submission to the Ontario Nuclear Safety Review, by Atomic Energy of Canada Limited, August 1987.

THE CHAIRMAN: Thank you.

MR. KING: Yes, that I have sentence now.

MS. McCLENAGHAN: Q. It says:

> In common terminology an inherently safe reactor is one in which under any conceivable circumstance the energy produced in the reactor can be safely dissipated to the environment by totally passive means. A passive means is one which requires no human intervention, nor source of external activating energy.

Is that the definition of passive that you mean when you say that you prefer that term?

MR. KING: A. That is the definition of passive that I prefer. It's not a universal definition of passive. Americans would not use that similar definition.

When it says here, you started in that sentence: In common terminology an inherently safe reactor... this document was written in August 1987 and I think I just mentioned earlier that it was more common then than it is now to use that terminology.

Q. And, of course, the situation is that the CANDU reactor does not have or does not shut down by means of passive, totally passive means.

A. Well, it shuts down by gravity. We would call our system, from an actuation point of view, to be fail-safe. A loss of power to any of the system will cause the reactor to be shut down. It doesn't require any human intervention to shut down. It doesn't require the existence of any external activating energy, the activating energy is gravity. Loss of electrical power will cause it to fail -- to fall, the rods to fall.

That's all I can say on it.

Q. So, in your use of the term passive safety rather than inherent safety, you are saying that the CANDU does shut down by passive means that you have just described?

A. Well, just looking at this sentence right here, shutdown systems do not require human intervention nor do they require an external activating energy.

MS. McCLENAGHAN: All right. That would be an appropriate place for a break, Mr. Chairman, if you wanted to sit until five o'clock.

THE CHAIRMAN: We are adjourned until tomorrow morning at ten o'clock.

THE REGISTRAR: This hearing will adjourn until ten o'clock tomorrow morning.

---Whereupon the hearing was adjourned at 5:00 p.m., to be reconvened on Tuesday, April 14, 1992, at 10:00 a.m.

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